The American Journal of Surgery

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SUTURES IN ANCIENT SURGERY

Jehan Yperman

(1280-1351)

SUTUREGRAM

NUMBER SIXTEEN IN A SERIES

Suture of Bronchial Stump

After pneumonectomy collapsible portion of lumen of bronchus is approximated to that held rigid by cartilaginous rings.

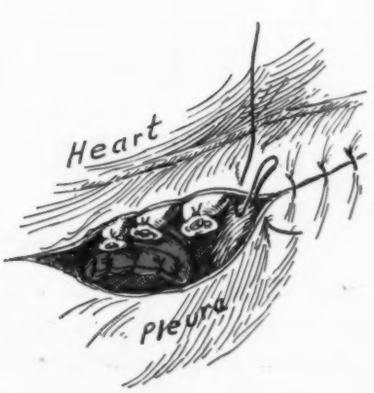
When mattress sutures are tied approximated edges are elliptical

SUTUREGRAM

NUMBER SIXTEEN (CONTINUED)

Interrupted sutures placed at very edge beyond mattress sutures help to make approximation airtight.

Visceral pleura is sutured over approximated bronchial stump and ligated blood vessels



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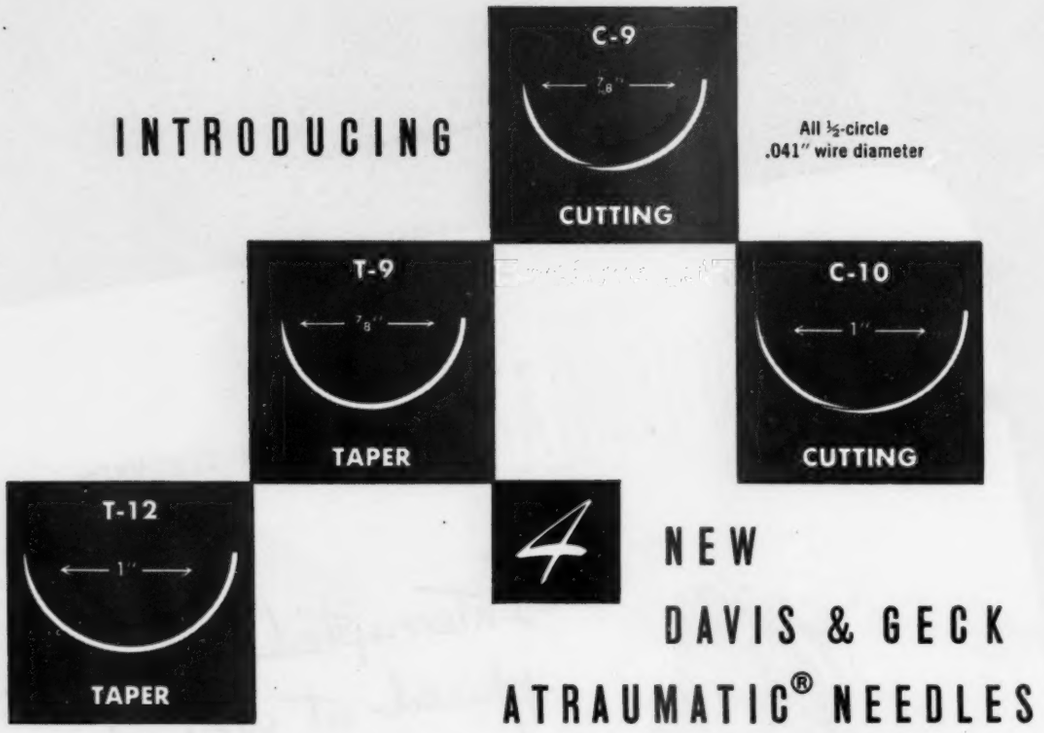

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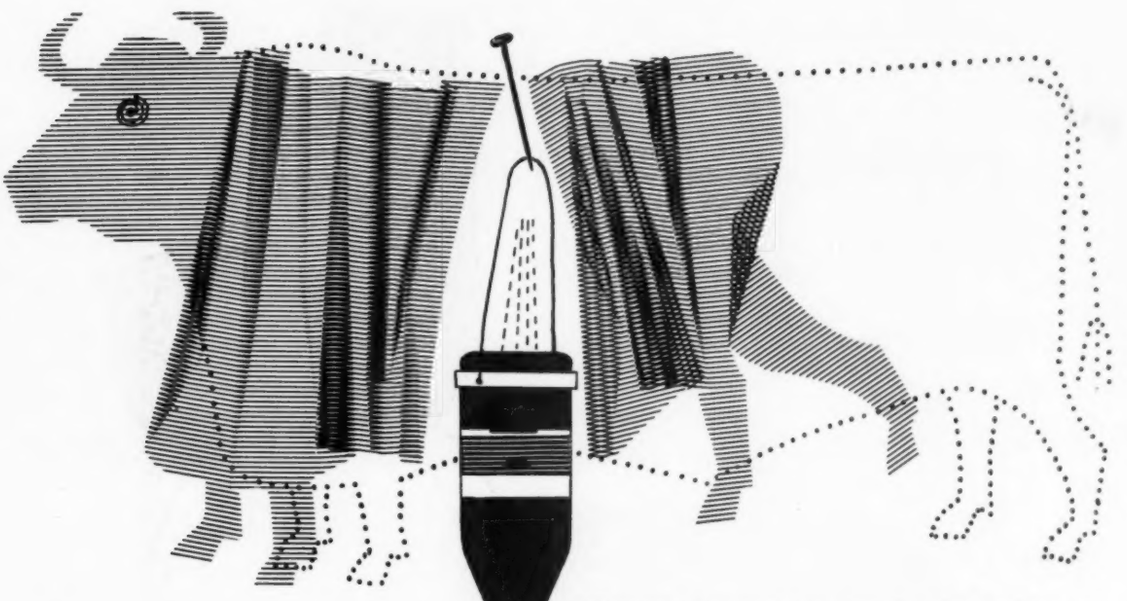

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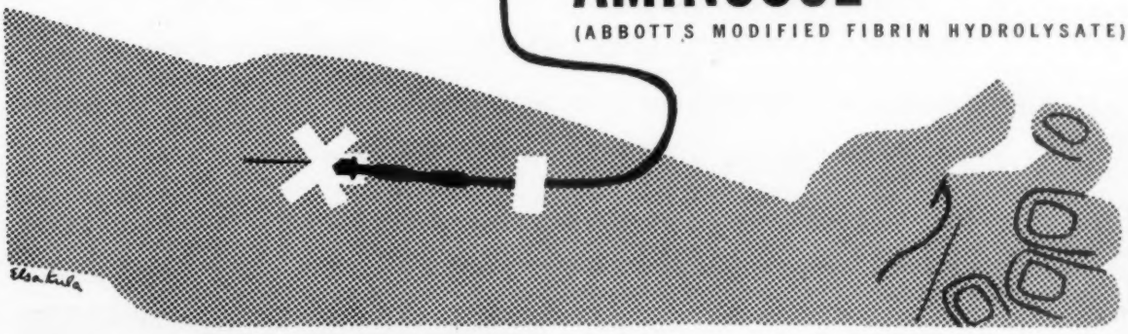

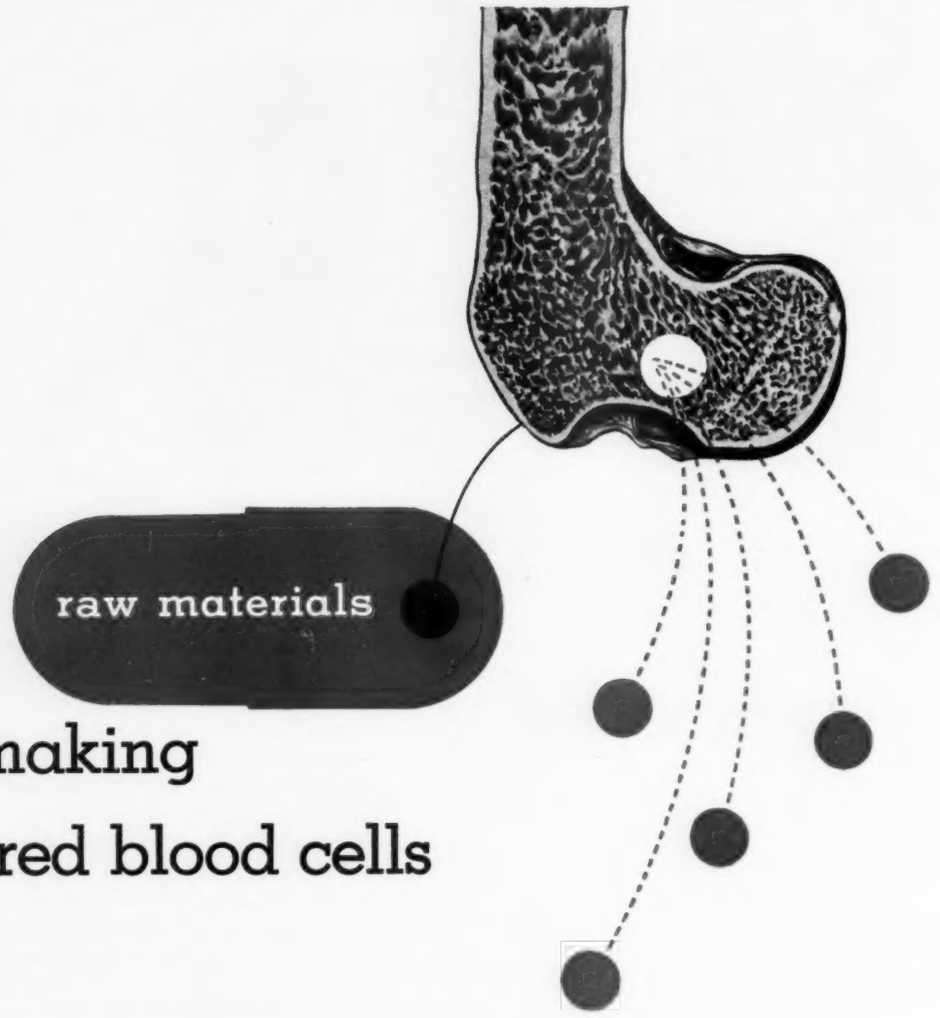

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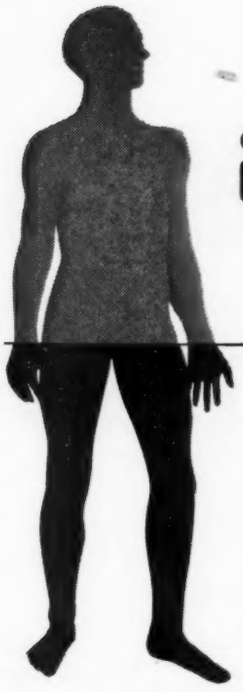

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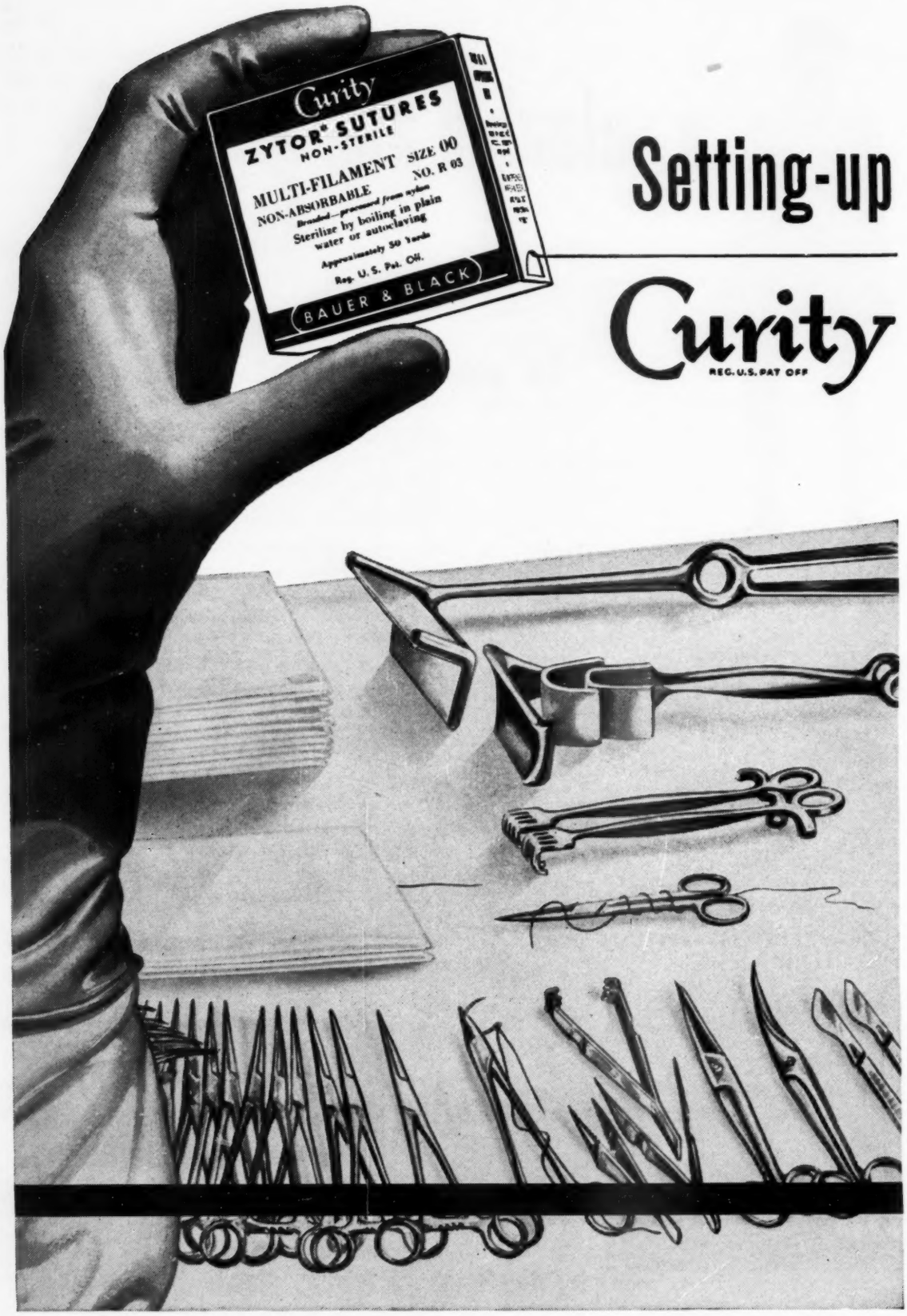

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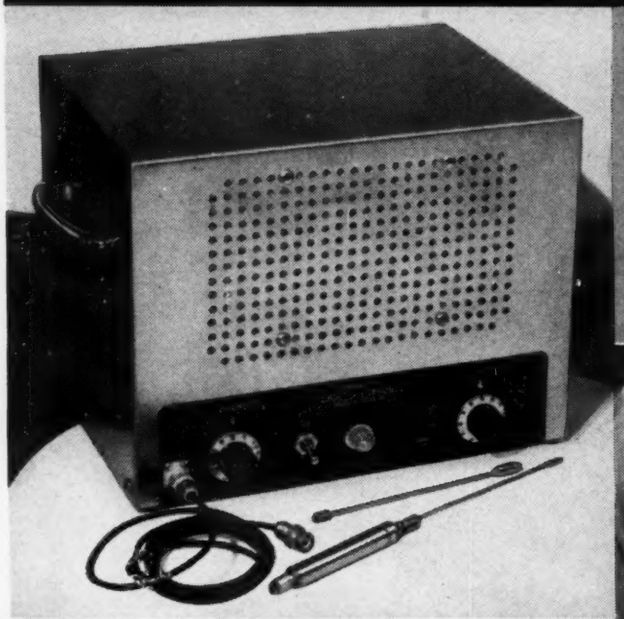

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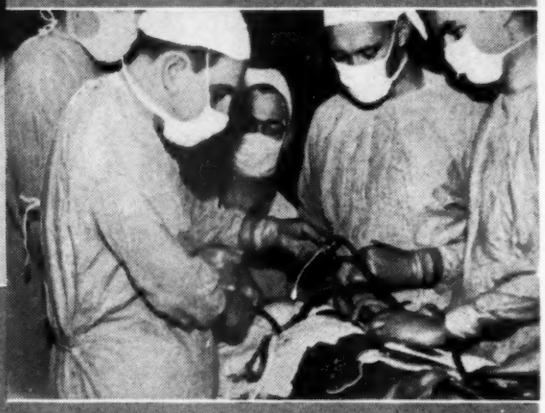

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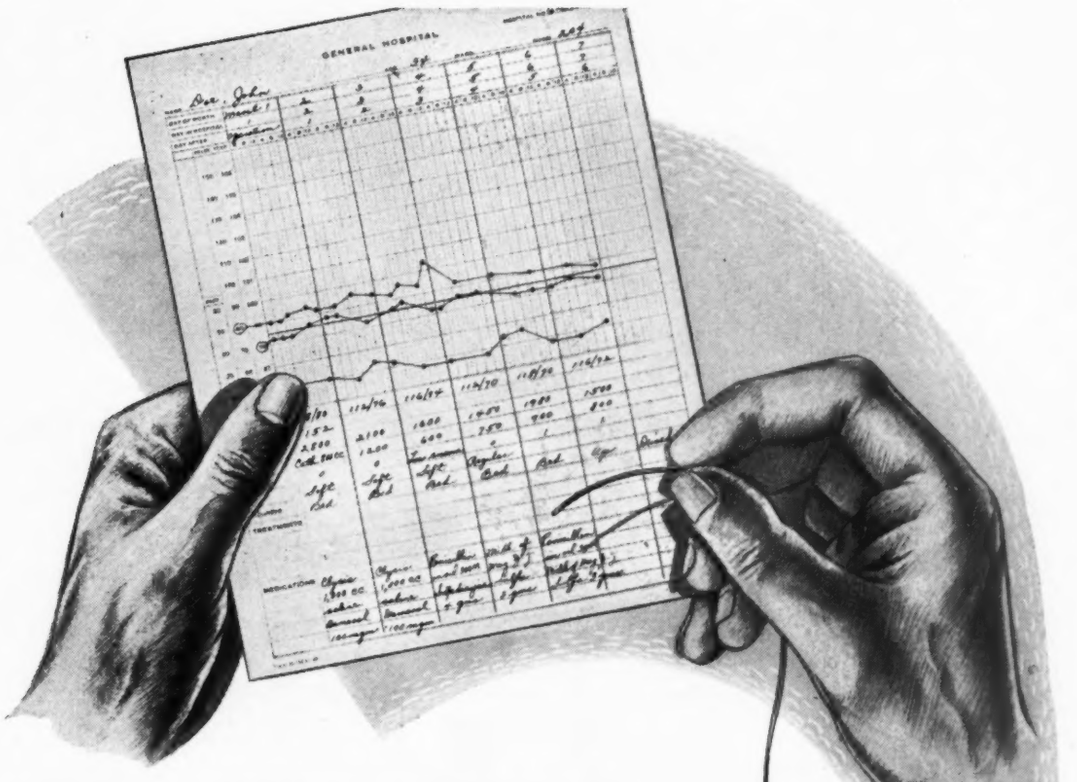

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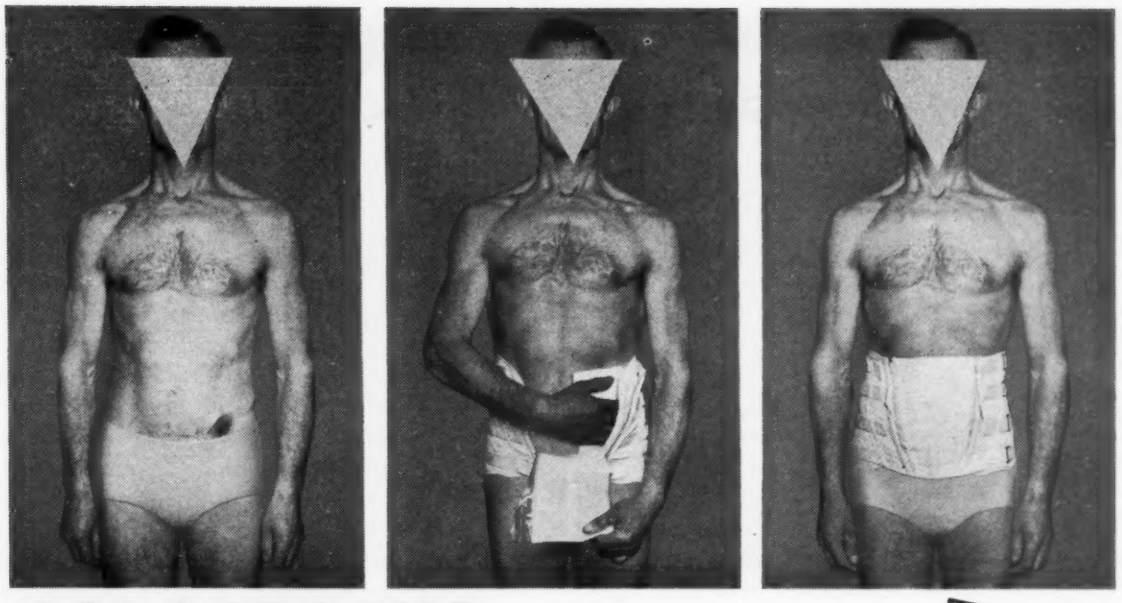

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[1]Hutchison, W. B., *Care of Colostomies*, Northwestern Medicine, 43: 107 (April) 1944. [2]Lahey, Frank H., *The Truth About Colostomy*, The Lahey Clinic Bulletin, 5: 130-136 (July) 1947.

Note on the patient shown above, these features in Spencer's new colostomy support:

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Outside the Ivory Tower

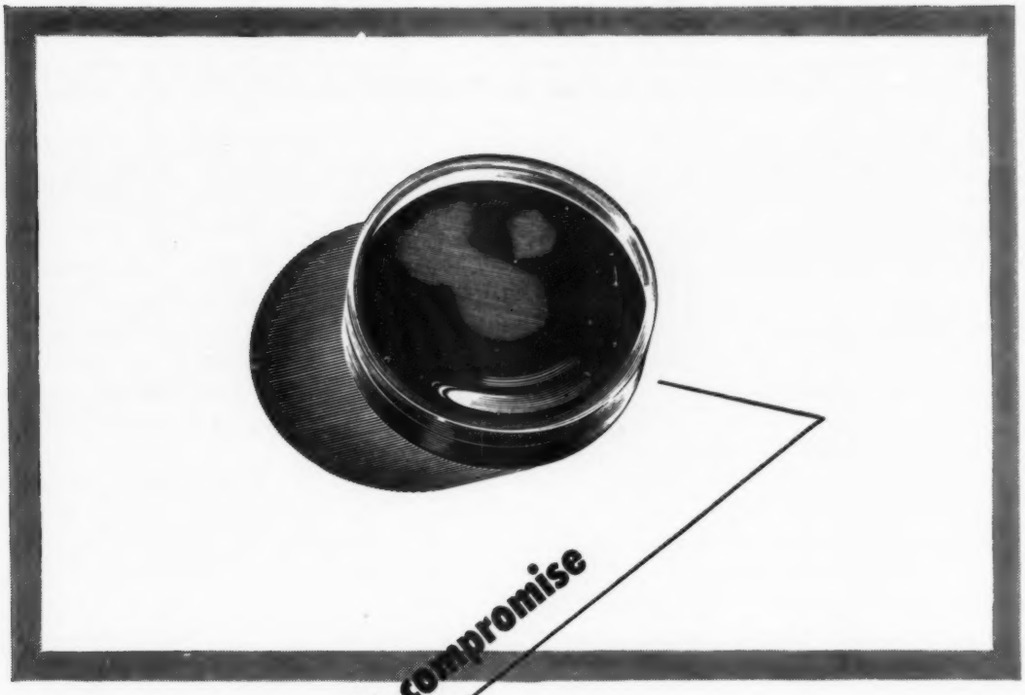
THE following comes only in part from an editorial in the August, 1949, issue of The Western Journal of Surgery, Obstetrics and Gynecology:

"The matter in hand has broken out of the usual editorial prerogative and rises immediately to a point of emotional tension: Facing the writer upon his clinical (not editorial) desk, are preemptory summons to essential medical meetings—five of them for one week, one eight A.M. hospital staff meeting, one eight A.M. clinical-pathological conference, one eight P.M. hospital staff meeting, one seven-thirty P.M. required departmental conference, one six-thirty dinner and evening with a specialty group. Unfortunately this is not at all an unusual situation. Often, as a matter of fact, there are also luncheon committee meetings, lectures and didactic and clinical conferences and what not. And now, suddenly and devastatingly—comes the realization that this is the month of August and here we are with this grim old albatros around our neck—a bird we were once, of yore, free to shake loose at least for the summer months! Because we are driven nearly insane with exactions of required local medical meetings and with the scattered and inconsecutive offerings of such meetings, we will refuse the temptation to benzedrine or strong drink and attempt here to set forth in a cool and reasonable temper, a few sensible considerations in this utterly hysterical field." The writer makes several sensible suggestions and we close with the following quote:

"If it were possible in the modern set-up for a physician to conduct his practice satisfactorily in a single hospital, the situation would be less onerous. This, however, is obviously quite impossible. Surgeries are too crowded, beds are too scarce, consultation requirements are too general. Physicians must belong to the staffs of at least two, often three, hospitals. It would be foolish to deny the favorable influence of such organizations as the J. A. M. A. and the American College of Surgeons in requiring periodic staff meetings. One is tempted to wonder, though, whether many hospitals may not now have earned the privilege to conduct their own business without the exactions of these centralized committees. Suppose we hypothecate that the influence has been excellent—so good in fact that hospitals now see their obligations clearly and will construct their own judicial disciplinary groups better than central committees in Philadelphia or Chicago? Suppose, for example, that larger hospitals, which have followed central requirements for a given number of years, be given a reward of merit in the form of a franchise in such matters? Suppose that certain physicians be allowed the credit and the privileges of membership in one hospital if they attend staff meetings in the other? It seems to us, speaking editorially, that the present machinery presupposes that we cannot come of age institutionally; that we must have the whip hand over us at every moment." This makes sense to many men. What do you think?

LATEST available figures show that the average length of life of the people of the United States is nearly two years above the level reached in the three years just before the war. "White women, on the average, live longer than any other single group, leading white men by more than five years," Mr. Ewing said. Average life expectancy for white women at birth is 70.6 years, while the average for men is 65.2 years. A total of 1,706,000 live births is estimated to have been registered from January through June of this year as against 1,694,000 for the first half of 1948 according to a report by Surgeon General Leonard A. Scheele of the Public Health Service. The only year in which the number of births in the first six months exceeded this year's figure was 1947 when the total for the period was 1,865,881.

(continued on page 20)



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Outside the Ivory Tower

(*continued from page* 18)

THE Macmillan Company offers us a book that all scholars and those who admire typographically fine books will welcome. It is certain to become a collector's item. It is "The Epitome of Andreas Vesalius," translated from the Latin with the preface and introduction by L. R. Lind, PH.D., University of Kansas, with anatomic notes by C. W. Asling, M.D., University of California, and a foreword by the late Logan Glendening, M.D. The Latin wood cuts and text of the original "Epitome of Andreas Vesalius" have been beautifully reproduced. All who are interested in the history and cultural aspects of medicine, and who delight in lovely things will treasure a copy of this, the first translation from the Latin of the famous work of Andreas Vesalius of Brussels. ($7.50.)

A NEW, third edition of "Tumors of the Bone" by Charles F. Geschickter, M.D. and Murray M. Copeland, M.D. is offered by J. B. Lippincott Co. ($17.50.) This is a large book of 810 pages, with 642 illustrations (more than 100 are new). This new edition has been revised and entirely reset. New entities in neoplasms of bone and in skeletal diseases of unknown etiology have been described; also new chapters have been added on Fibrous Dysplasia, Variants of Neoplastic Ossification and Tumors of the Spine. The tabulations of bone tumors, which represent the fundamental material on which this work is based, include over 500 additional cases. At the end of each chapter is a bibliography and there also is an Index. To any one interested in this subject we recommend this work and consider it A-I.

IT is merely our desire to bring to your attention and advise you that each of the following books are good, authoritative treatises which we highly recommend:

"Fundamental Considerations in Anesthesia" by Charles L. Burnstein, M.D. The Macmillan Co. $4.00.

"Histology and Histopathology of the Eye and Its Adnexa" by I. G. Sommers, M.D. (Invaluable for medical students, interns and residents in ophthalmology.) Grune & Stratton. $12.00.

"Textbook of Histology" by José F. Nonidez, late professor of Anatomy, Cornell University and Professor of Microscopic Anatomy, University of Georgia, and William F. Windle, Professor of Anatomy, University of Pennsylvania (452 pages, 209 drawings and 193 photomicrographs). McGraw-Hill Book Company. $6.75. (A well worth while book—should have a wide appeal to medical undergraduates.)

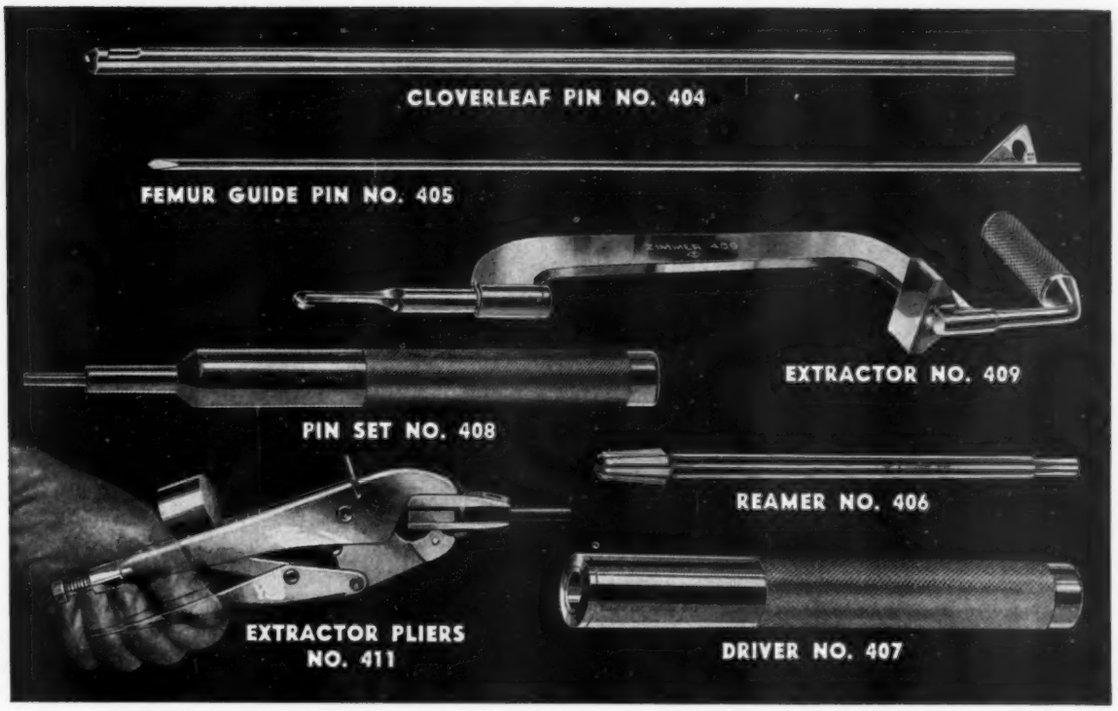
"Pathology and Surgery of Thyroid Disease" by Joseph L. DeCourcy and Cornelius B. DeCourcy. (Based on personal experience in over 15,000 thyroid conditions.) Charles C. Thomas. $10.00.

"The Technic of Pulmonary Resection" by Richard H. Overholt, M.D. and Lazaro Langer, M.D. (Technical problems which confront the thoracic surgeon.) Charles C. Thomas. $6.00.

EVERY physician should own a Medical Dictionary; in fact, he should own the latest standard medical dictionary. Medicine and all its branches rushes on apace and the amazing discovery of last year is an accepted commonplace today. Nearly forty years ago our dictionary was a slender thing. Now, the New Gould Medical Dictionary has been published by The Blakiston Company. It is almost beyond description. It has grown from the affair of my neophyte days to a tome of 1,294 pages. It has 252 illustrations on 45 plates, 129 in color. The editors are Harold Wellington Jones, M.D., Normand L. Hoerr, M.D. and Arthur Osol, PH.D., with the coöperation of an editorial board and 80 contributors. How can one tell another what is inside a new, modern medical dictionary? Suffice it to say everything is contained in its pages. We spent almost an afternoon browsing from page to page. It is a First Edition; it is the latest of its kind. We recommend it to everyone who at any time has occasion to use a dictionary of this type; it is a gem of medical editing and publishing.

TWO volumes (1,024 pages) have been published by The Livingston Press (Livingston, N.Y.) by Maya Riviere on "Rehabilitation of the Handicapped." The foreword is by Holland Hudson, of the National Council on Rehabilitation. The volumes detail a bibliography from 1940 through 1946. It is a guide to thousands of the best reported studies which have been made of handicapped persons and to what has been done to restore them to "the fullest physical, mental, social, vocational and economic usefulness of which they are capable."

(*continued on page* 36



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*BOEHME, E. J.	The Treatment of Chronic Leg Ulcers	The Lahey Clinic Bulletin, 4:242 (1946)
BOWERS, WARNER F.	Chlorophyll in Wound Healing and Suppurative Disease	Amer. J. Surgery, LXXIII:37 (1947)
CADY, JOS. B. and MORGAN, W. S.	Treatment of Chronic Ulcers with Chlorophyll	Amer. J. Surgery, LXXV:4 (1948)
CARPENTER, E. B.	Chlorophyll Therapy in 127 Cases of Chronic Osteomyelitis and Ulcers	Amer. J. Surgery, 77:162(1949)
JOHNSON, HAROLD M.	Dermatologic evaluation . . .	Arch. Dermat. & Syph. 57:348 (1948)
LANGLEY, W. D. and MORGAN, W. S.	Chlorophyll in the Treatment of Dermatoses	Penn. Med. Journal, Vol. 51; No. 1 (1948)

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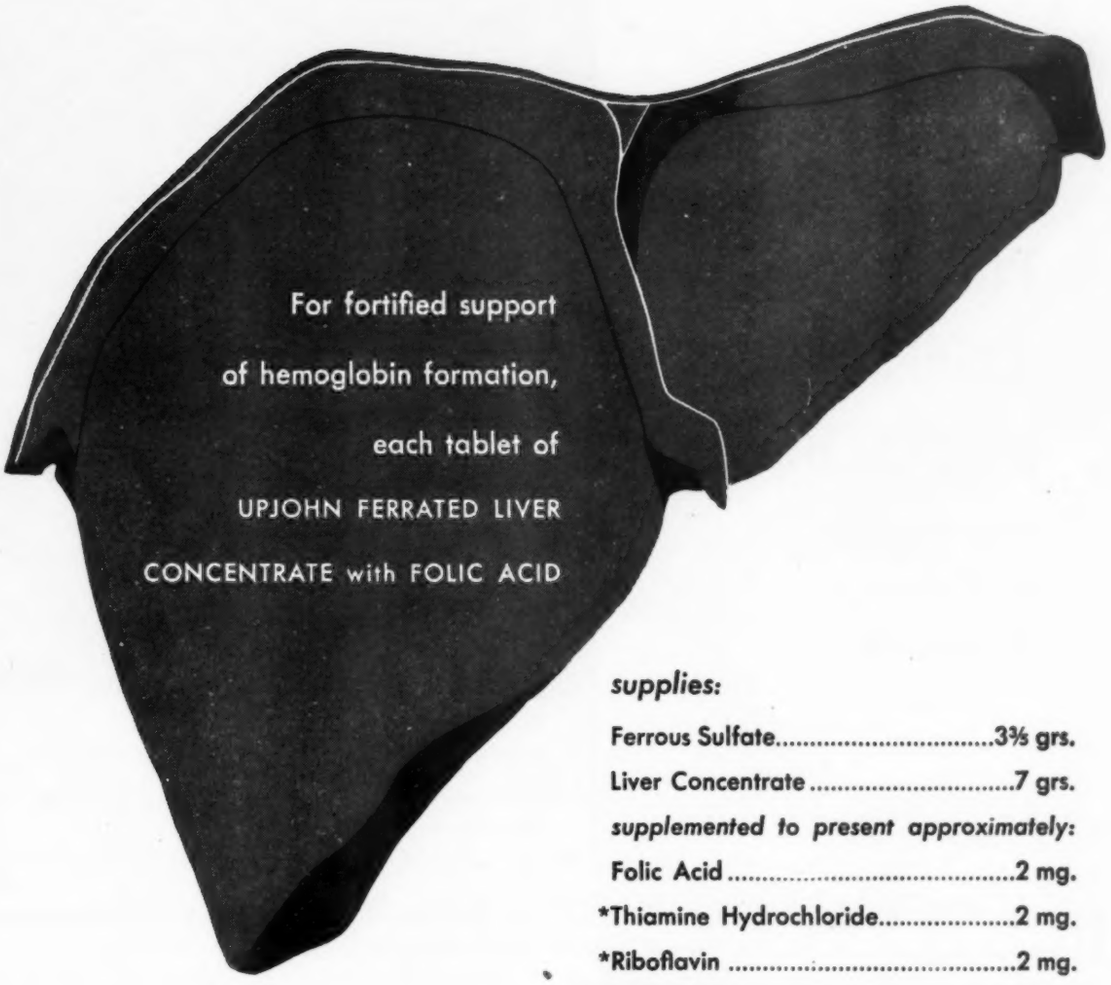

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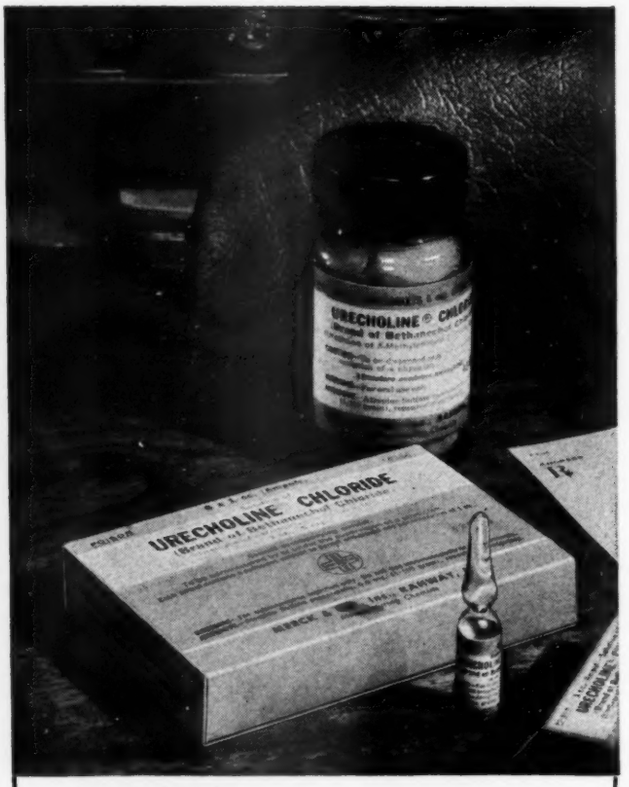

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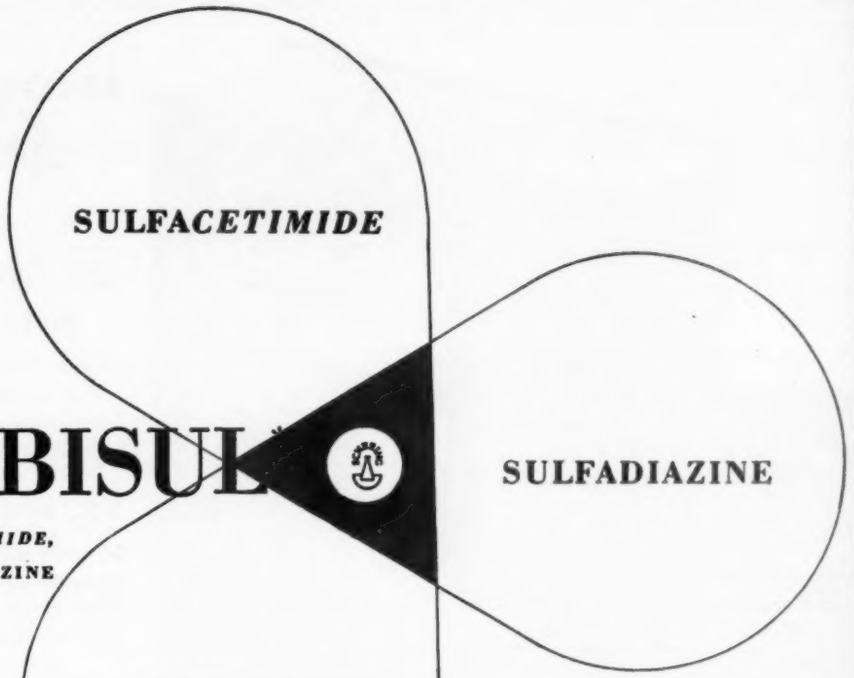

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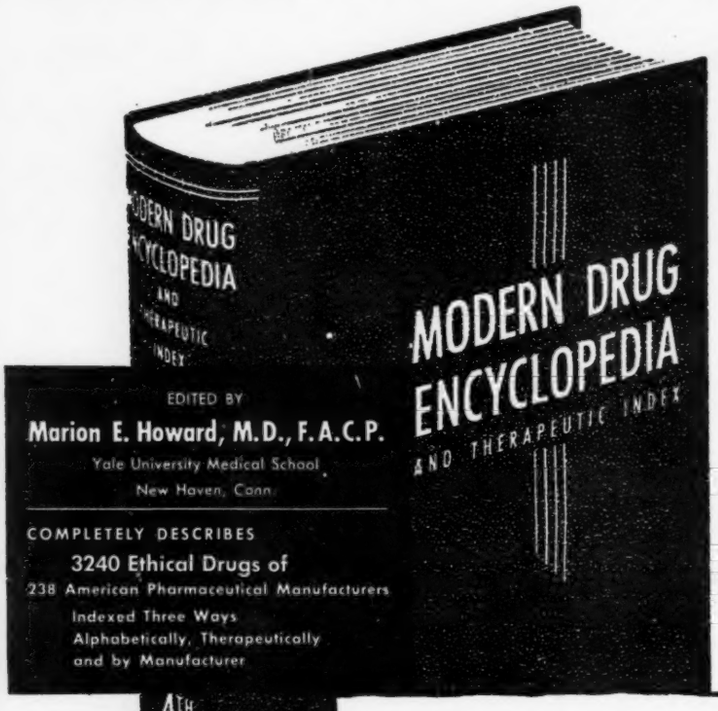

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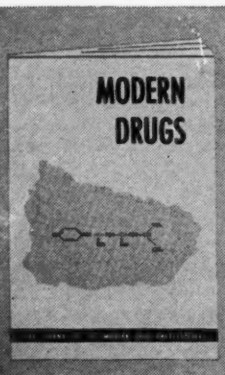

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On this Important Subject

of Breakfast...

and Sustained Mental Acuity

The complexities and fast pace of modern living demand—for safety's sake—that mental acuity be sustained in both adults and children, at highest pitch throughout the day, including such times as the pre-noon hour when alertness may wane. In this light, recent studies* at a prominent medical college proving that adequate breakfasts are required for sustained morning mental acuity extending through the pre-noon hour assume especial importance.

A Good Breakfast.. Improved Mental Acuity

In this study, conducted jointly by the departments of physiology and nutrition of a prominent medical college, a direct relationship between late-morning mental acuity and breakfast habits was definitely established. The experiments were planned to learn whether eating breakfast, and eating no breakfast or taking coffee only, influenced the subjects' mental acuity during the pre-noon hour.

Six young women graduate students were used as subjects and mental acuity was determined by measurement of simple and choice reaction times to light stimuli. These experiments definitely showed:

(1) That the *omission* of breakfast increases reaction time, hence acts detrimentally;

(2) That when breakfast is eaten, reaction time is reduced—hence favorably influenced.

In other words, eating breakfast better prepares one for the demands of living and from a practical standpoint, serves as a safety precaution against potential accidents due to breakfast skimping or skipping.

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*Reprint of the study will be sent upon request.

The presence of this seal indicates that all nutritional statements herein have been found acceptable by the Council on Foods and Nutrition of the American Medical Association.

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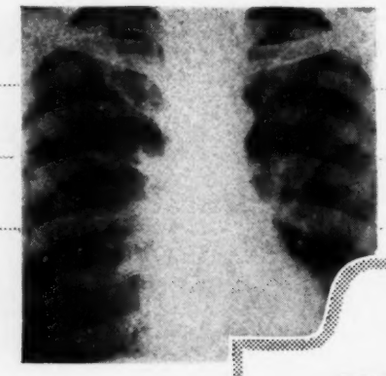

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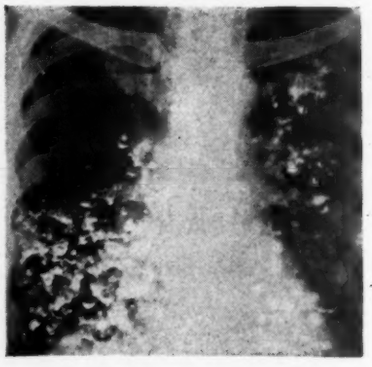

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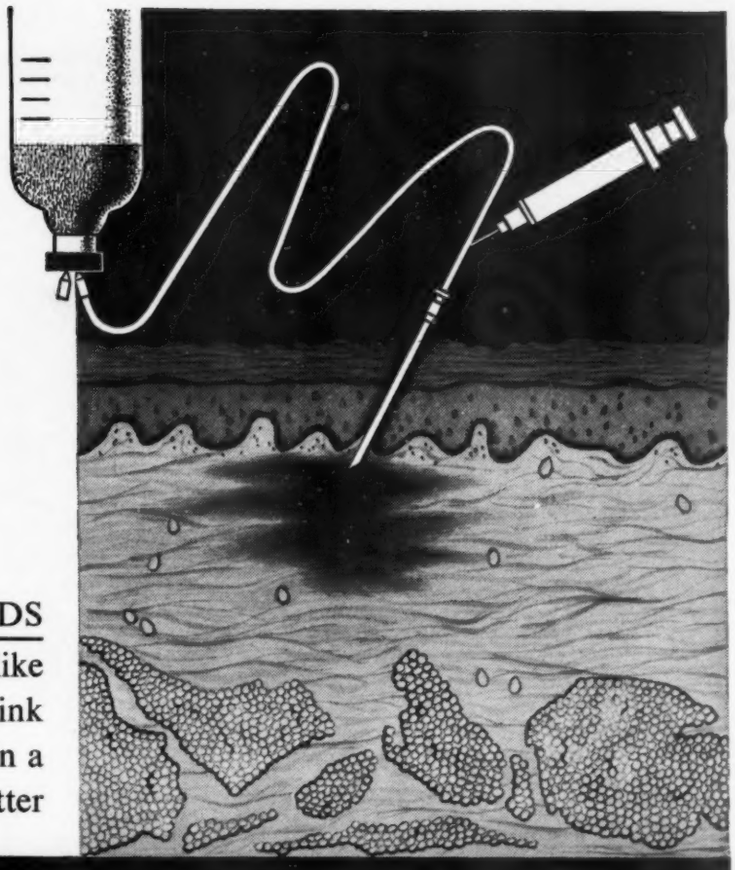

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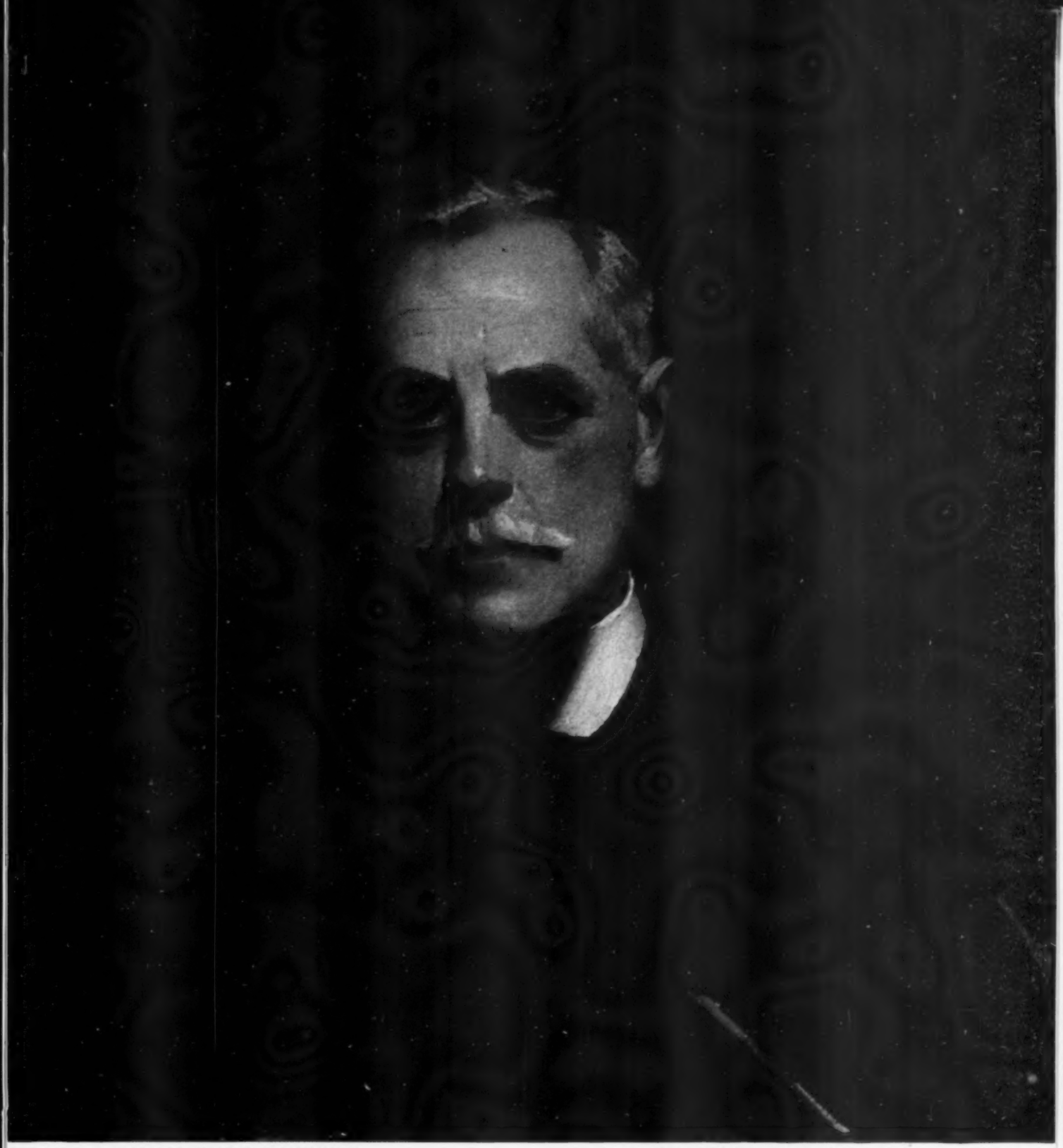
*Coakley, W. A. et al.: Plast. & Reconstruct. Surg. 3:667 (Nov.) 1948 • Curtis, L.: Surg. Clin. N. A. 1466 (Dec.) 1947 • Mills, J. T. et al.: Plast. & Reconstruct. Surg. 3:245, 1948 • Shipley, E. R. et al.: Surg., Gynec. & Obst. 84:366, 1947 • Snyder, M. L. et al.: Mil. Surgeon 97:380, 1945 • Teplitsky, D. et al.: Plast. & Reconstruct. Surg. 3:189, 1948.



FROM THE PAINTING BY FRANK O. SALISBURY

COURTESY, JOHNS HOPKINS HOSPITAL

William Holland Wilmer

1863-1936

A graduate of University of Virginia, Dr. Wilmer studied at New York Polyclinic and various European hospitals. Beginning the practice of ophthalmology in New York in 1906, he became professor of ophthalmology at Georgetown University. In 1925 he went to Johns Hopkins University as professor and ophthalmologist-in-chief to Johns Hopkins Hospital.

The Wilmer Institute, of which he was Director, was created as a tribute by friends and patients. Dr. Wilmer served as an overseas medical officer during the first World War and was a Brigadier General in the Medical Reserve Corps. He was a founder of the American College of Surgeons and contributed much to the literature on ophthalmology.

From the Series, Great American Surgeons, Published By

ETHICON SUTURE LABORATORIES, DIVISION OF JOHNSON & JOHNSON, NEW BRUNSWICK, N. J.

Chicago, Ill.—Photograph in Ethicon Suture Laboratories, showing ribbons of surgical gut being inspected just prior to immersion in chrome bath. After chromicization several ribbons are spun into a completed suture strand. Tru-chromicizing before spinning, an exclusive Ethicon process, assures uniform chrome disposition, resulting in uniform digestion by tissue enzymes.

Why you get a better suture

WITH ETHICON'S TRU-CHROMICIZING PROCESS

The fate of the absorbable suture after implantation and wound closure, and its reactions in the host, are the ultimate test of the suture's quality and dependability.

Today chromicized gut is widely used because of its resistance to digestion until healing is accomplished. In this aspect, the chromic suture must possess these attributes:

1. Sufficient chrome content to withstand premature digestion.

2. Chrome concentration must not be so excessive that fragments of the suture resist digestion and persist in tissue. This condition frequently leads to knot extrusion.

In order to obtain a product having the highest possible degree of uniformity, Ethicon chromicizes raw gut strands in the ribbon stage. This more meticulous process was named Tru-chromicizing. The alternative method, used by others, called surface-chromicizing, involves the dipping of the finished, spun and dried suture strand in a chrome bath. These are the results of the two methods:

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In enzyme solution, the core of most surface-chromicized gut digests readily, leaving a hollow cylinder which separates into ribbons.

This cylinder may be excessively resistant to enzyme action and remain as an undigested foreign body indefinitely.

Tru-Chromicizing

Ethicon Tru-chromicized gut exhibits uniform enzyme resistance throughout digestion. It digests from the surface inward, and retains its integrity as a unified suture until dissolution approaches completion.

Total digestion eliminates the danger of knot extrusions and sterile stitch abscesses.

What Tru-Chromicizing Means To You

1. Less interference with healing through minimized foreign body reaction.

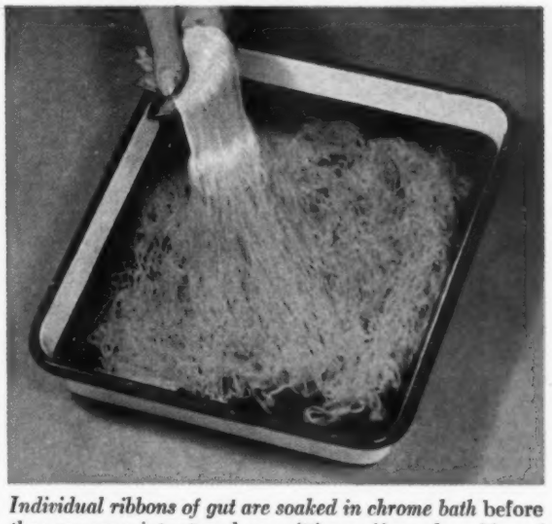
2. High tensile strength of suture retained for the healing period, followed by complete absorption.

3. Uniformity in those physical and physiologic characteristics essential to accurate surgical technic.

SURFACE-CHROMICIZING*

When gut is chromicized after strands are spun and dried, chrome concentration is very high in surface layers and relatively low in the core. Inner core is digested rapidly—the highly chromicized periphery survives for prolonged periods.

ETHICON TRU-CHROMICIZING



Individual ribbons of gut are soaked in chrome bath before *they are spun into strand, permitting uniform deposition of chrome. The strand thus has the same chrome content from periphery to center.*

ETHICON *Sutures*

***To illustrate this comparison, small laboratory trays are used. In commercial production, surface-chromicizing is done under tension. Both processes are performed in large vats.**

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A PRACTICAL JOURNAL BUILT ON MERIT

Fifty-eighth Year of Publication

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Editorial

PRESIDENTIAL ADDRESS

PAUL B. MAGNUSON, M.D.

Washington, D. C.

I SHOULD like first to thank the officers of the Association for their cooperation during my term of office. This is a marvelous group with whom I have been associated. I am sorry that I have not had more opportunity to carry my share as an officer but I have always tried to follow the dictum laid down by J. P. Morgan, true executive ability consists of having others work for you.

While listening to the program and seeing those beautiful movies which depict so clearly many things which cannot possibly be understood unless actually seen, it was brought home to me how far the surgery of trauma has advanced in the past forty years. It is just that long this month since I started in practice and I would like to paint from my own experience a picture of what was going on forty years ago and what has been achieved. I think it is interesting to speculate upon the influences that decisions made in early life have on a man's subsequent career. I remember how I chose the location for my first office. It was two small rooms above a saloon at Root and Halsted streets at the main entrance to the stockyards in Chicago.

At that time I was supposed to be Dr. J. B. Murphy's assistant. No assistant was paid in those days; his apprenticeship with his chief was presumed to more than remunerate him. In fact he sometimes paid for such apprenticeship. In common with most other young doctors in those days, I had had no internship and no residency, and probably was not worth much anyway. When I decided to open my own office, I discussed the matter with Dr. Murphy who advised locating in the stockyards district. Those of you who know Chicago know what Halsted Street was and is. He said that for one interested in bone and joint surgery the industrial district was the place to obtain experience and he was right. I had a further incentive for wishing to blossom out on my own. I wanted to marry the girl to whom I had been engaged for some time and I thought there would be more prestige in having my own office than in being an assistant, even to John B. Murphy. She was in complete agreement with this. We therefore combed the stockyards district, riding up and down Halsted Street by trolley car until we came to Root and Halsted. There was plenty of activity at that corner and we thought that this was a good place so we looked for a location and finally selected the two rooms over the saloon on which the rental was $35 a month, which was a lot of money.

I had a vague acquaintance with an official of one of the packing houses and, after waiting in vain for some time for patients to flock to my door, I went over to see him. As a result he gave me a letter of introduction to the president of the Chicago Junction Railway, a switching railroad that handled incoming and outgoing freight from the yards. After some preliminary skirmishing he promised that all calls which could not be taken care of by the company doctor would be referred to me. To him that was

probably just a way of easing me out but to me it meant the God-given opportunity to "strut my stuff" when, as and if patients materialized. And they did materialize. The first patient who came in was Mike McKenney, bless him, and I shall never forget that name. Mike had a fissure fracture of the patella. I knew enough about the knee joint to decide the ligament was intact and he probably would get well if I kept hands off. But it was a fractured patella. It happened that two railway employees had had fractured patellas, one two years and one three years before. Both had been operated upon and were still laid up. I did not operate on my patient but applied adhesive strapping and a posterior splint and turned him loose. He walked from one end of that district to the other telling them what a great man I was. When he got well and was able to return to work in eight weeks or so my reputation was made. The grapevine works well in a self-contained district such as the yards. The other two men were still laid up.

I was still working at Mercy Hospital and, having no secretary, switchboard operator or "receptionist," the problem arose of what to do when calls came to the office and there was nobody to receive them. In those days the saloons were open twenty-four hours a day, with a bartender or two always on duty. I decided to ask my landlord, the saloonkeeper, whether I might have an extension telephone run from the bar to my office. This was agreeable to him and I thought this took care of the situation, in part at least. However, business still had to be drummed up so in odd moments it was necessary to contact the timekeepers in the various plants. These were the key men so far as accidents were concerned and most of them were willing to call me when the company doctor could not be reached. I told them there was twenty-four-hour telephone service at my office and there was. The bartender who took the call would say that I had stepped out for a few moments and to send the patient over. Then he would phone me at Mercy Hospital, about 1½ miles away, and I would dash out in my little two-cylinder automobile (some of the old-timers may remember them) and take care of the patient.

By such devious means we made a start in industrial bone and joint surgery—possibly unfair competition in cutting in on the practice of the established men in the community. I doubt if such methods would be approved of today. But we were taking care of injured and sick people; we were hospitalizing many more patients than had been the custom. Any badly injured man was sent to the hospital and given the best care that could be given. This, of course, caused repercussions in the claims departments whose motto in those days was to settle an accident case promptly and as cheaply as possible. There were no Industrial Commissions then and the services of doctors and hospitals were not regarded highly in the minds of those who handled the claims.

The type of surgery performed forty years ago was extremely crude by present standards. So far as I can remember we had no anesthetics except chloroform, ether and nitrous oxide. We had no facilities for transfusions, no intravenous salt or glucose solutions nor any of the other adjuncts we take for granted today. So far as sterile dressings were concerned we were in what Dr. Murphy called the "mason jar" stage of hospital equipment. Practically all the dressings at Wesley Hospital (the University Hospital of Northwestern University) were in baskets filled with mason jars into which dressings of various sizes had been packed and then sterilized; in the corner of the basket was a Kjelland's forceps in a jar of 70 per cent alcohol. But to sterilize the instruments—who ever heard of using sterile instruments for ordinary dressings? We had designed and made what I believe was the first dressing cart used in Wesley Hospital. It worked and was popular so that whenever I needed it, it was in use. In order to reserve it for our own use I covered it with a sheet of iron equipped with a padlock to avoid having to track down Allan Kanavel or Sumner Koch or others I might mention. X-rays were far from adequate. Hollis Potter had not yet designed the Potter-Bucky diaphragm and an x-ray of the spine looked like a snowstorm. At times the outline of the spine could be seen vaguely but in a fat person even that was almost impossible.

Those are a few of the handicaps we had to contend with. The motor-driven bone saw and the other instruments we take as a matter of course were practically unknown in the average hospital. I had designed a motor-driven saw the year I graduated from medical school; Albee's came out about the same time. The saw required careful handling and was tricky but worked well. One of my good friends who had seen me use it asked if he might borrow it for a bone-grafting operation. I loaned it to him and

in the process of getting the graft out the saw whipped around and cut off his interne's finger. So far as I know he has never used a motor-driven bone saw since that day and much prefers to take out the graft with chisels.

When the Red Cross and first aid program started, Dr. H. W. Gentles was the man who instituted the training of teams in first aid care in Chicago in the stockyards and other places. This, I think, was the original effort made by the Red Cross in teaching laymen. Then, about 1914, the compensation laws were enacted in Illinois and for several years they were in operation without having a medical director. Incidentally, these laws were fought tooth and nail by employers as well as by the medical profession. When they were finally passed, it was found necessary to have the services of someone who could interpret the findings before the Industrial Commission. Unfortunately, at that time the type of doctor who went into industrial medicine was dependent many times upon the favor of the claims agent and too often he became the tool of the claims department to the point that industrial medicine as a whole was looked upon with disfavor by the medical profession and the population in general.

One experience I had with the railway company is worth relating. I had a letter from the company returning a bill which I had rendered, a rather steep bill, saying that this should be reduced or they would get another doctor. I went over to see the president of the company, in no sweet frame of mind, in spite of the fact that the money I received from the railway constituted a substantial part of my income. I told him that if I were to cut the bill, it would be an acknowledgment that I had made it too high in the first place and I would not admit that. I also said that if he did not wish to have his injured employees treated in the same way I would treat him if he were injured, he could get another doctor but that the bill was going to be paid. I stalked out but I must have impressed him because the bill was paid. Via the grapevine I learned that the claims department had been instructed not to question my bills in future. This was the beginning of the educational campaign carried on not only by that company but also those elsewhere in Chicago to educate executives in the humanitarian principles of saving life and limb. It was the beginning of the safety campaign which has become nation wide in scope and is now taken for granted.

The insurance companies came into the picture because they found that safety measures saved money. There were no safety devices on machines. It was long before workmen were required by law to wear goggles when operating grinding machines. There were no rules against kicking over a draw bar with the foot, with the hazard of catching the foot in the machine. In one week I performed seven amputations for one company, which shows the terrific chances these men took. When I became Medical Director for the Illinois State Industrial Commission I thought that I was in a strong position to carry on an educational campaign not only for accident prevention but also for proper care of accident cases. And education was needed. It was disheartening, for example, to see what could happen to a dislocation of the wrist. It might be treated by exercise for several months, exercises which tore the structures of the wrist to the extent that it became necessary to remove the semilunar bone; and when this was done, it might be found several months later that the median nerve had been cut at the time of operation. Fractures of all types were treated abominably prior to 1922 when the Fracture Committee of the American College of Surgeons was formed. This Committee has been largely instrumental in the education of the general practitioner throughout the country.

A coal mining company in southern Illinois asked me to make a survey of their field to see what could be done about improving medical care. I found not a single graduate of a Class A school in the county nor was there a hospital in the county. I cannot remember how many compression fractures of the spine, malunited and ununited fractures, painful wrists and ankles, and poor surgery I saw during the first few weeks I was there. For four years I spent two days every two weeks in that town and sent all the surgery to Chicago. Now they have a pretty good hospital. The mining companies got together and built the hospital and secured a fairly well trained staff. They have decided that it is better to give good medical treatment than to pay what may be assessed against them by the Industrial Commission.

I did not start out with the idea of giving you a learned dissertation and I am sure you will agree that I have not done so. I have merely related some of my own experiences in the evolution of industrial surgery, the surgery of trauma. To some of the younger men in this

group the conditions with which we had to deal forty years ago may seem inconceivable. The progress that has been made in the last fifteen years alone has been astonishing. It is extremely gratifying to one who went through the days when it was considered rather a disgrace to have anything to do with industrial surgery; it smacked of commercialism and, indeed, in the past I have been tagged with that epithet, commercial doctor. It is particularly gratifying to know that through the efforts of many of our best surgeons the element of commercialism has been largely overcome in industrial surgery and that through education and guidance, through adherence to the principles of the "good doctor" many lives have been saved and many crippling accidents avoided.

Original Articles

LIVING WITH WHAT'S LEFT*

HOWARD A. RUSK, M.D.*
New York, New York

REHABILITATION, like traumatic surgery, is made up of many components. Those interested in traumatic surgery must first have the basic groundwork training in general surgery; they must know orthopedics, industrial problems and the problems of plastic and chest surgery; they must be familiar with the compensation laws, the problems of pensions (not only dollar-wise but the psychological problems) and, above all, they must have a fundamental interest in the patient. The ultimate objective after surgery is done and the stitches are out is: What can this man do with his life?

Rehabilitation is also a program of many facets. In the first place any program of rehabilitation is only as good as the sound medicine that backs it up. This is fundamental. The diagnosis must be accurate and definitive medical and surgical care must be the best. Then comes the problem of training the individual to live with what he has left. The first phase of medical cure is, obviously, prevention; the second phase is definitive medical and surgical care. In our department at New York University and at Bellevue Hospital we talk now about the third phase of medical care, that period between the bed and the job, a period in the past when many patients had been lost. They were not lost because of death but because we had failed to provide them with the opportunities to learn to live and work with what is left; lost because they had been infected with that insidious disease "hospitalitis."

A well planned, total rehabilitation program is just as important to those interested in traumatic surgery as a well equipped operating room. Without either one you cannot do a complete job.

A rehabilitation service in a hospital should function as a service department, just like the laboratory and x-ray, and should start in the medical and surgical wards. With the amputee it should begin, if possible, before the surgery is done; if not, just as soon as the patient is able to participate in a planned physical and psychological program designed "not just to get him out of the hospital but to take him as far as he can go."

The total rehabilitation team consists of, first, the doctor who is trained in this field. A new specialty board has been established in the American Medical Association known as the American Board of Physical Medicine and Rehabilitation. The requirements are as rigid as any of the other boards and the years of special training required are comparable. However, an individual with good, basic training in surgery, orthopedics, medicine or neurology can learn the essential fundamentals of rehabilitation in a year's time in a properly organized hospital training program. Already the Board of Internal Medicine gives credit toward certification for training on such a service as we operate at Bellevue Hospital, and the Council on Medical Education and Hospitals has published standards on such services in a general hospital.

We see prospective candidates for rehabilitation on the request of other services and after consultation if we think that they can be aided by a training program, such a program is started in their own wards. At the appropriate time these patients are transferred to the rehabilitation wards. At this time our service takes over the major responsibility and the referring service acts in a consultative capacity.

After a check on the general diagnostic

* Professor and Chairman, Department of Rehabilitation and Physical Medicine, New York University College of Medicine, New York, N. Y. The following is an adaptation of an extemporaneous address given at the annual dinner of the American Association for the Surgery of Trauma in Atlantic City, New Jersey, June 3, 1949.

studies the patient must be tested for muscle strength, joint range of motion and in the inherent needs of daily living. In the Rehabilitation and Physical Medicine Service at Bellevue Hospital a check list of ninety-six items is used to determine these factors. They include: first, bed activities such as moving from place to place in bed and the ability to sit erect; second, toilet activities; third, eating and drinking; fourth, the ability to dress and undress such as tying shoe laces, manipulating buttons, zippers and other fasteners and applying and removing braces; fifth, hand activities, for example, winding a watch, striking a match and using various door knobs and latches; sixth, wheel chair activities, getting from bed to wheelchair, wheelchair to bed and in and out of the bathtub; finally, elevation activities which include the needed abilities for walking, climbing and traveling.

At first glance such a test list sounds formidable and time-consuming but in reality the information may be easily obtained by a therapist, nurse, a well trained volunteer or a member of the patient's family. From special check sheets used for charting the activity accomplishments, information is readily available both on the status of the patient at the time of admittance and his progress while undergoing rehabilitation.

The use of such a check list is particularly helpful if personnel are not available to do definitive muscle testing and accurate range of motion determination for the daily activities test can be completed in the hospital, the physician's office or the patient's home. The subsequent training program is designed to teach the patient the various skills and activities which he cannot perform.

In Bellevue Hospital and the Institute of Rehabilitation, after the basic medical work-up and the range of motion, muscle and needs of daily living tests, the physician, in conference with other staff members, prescribes a five hour a day program for the patient. These prescribed activities include training in the ambulation and elevation rooms and the remedial gymnasium, occupational, physical and speech therapy or any other activity which may be helpful in meeting the specific needs of the patient.

In a comprehensive rehabilitation program vocational guidance specialists should also be available for guidance and to do testing in order that the patient may be started on a prevocational exploratory and work-testing program as soon as it is medically feasible. However, good basic rehabilitation can be carried out with the personnel available in the ordinary general hospital if such a program is properly organized, supervised and prescribed by the physician.

Although in this country we have the finest institutions in the world for definitive medical care and vocational training, outside of the military services and the Veterans Administration there are but a small handful of civilian agencies and organizations equipped to provide for the patient with a physical disability the necessary retraining in physical skills which are a requisite for later vocational training.

The physician in the past has thought too much about the physiological and clinical aspects of the patient's disability. The vocational counselor too frequently has thought only in terms of physical skills which could be utilized vocationally. Between the two, however, there is a wide area through which most physically handicapped persons must go when their definitive medical care is completed but before they are ready to undergo vocational training. In this area lies the physical retraining in skills necessary for the carrying on of the activities inherent in daily living and common to all types of work.

Except in a few isolated instances the physically handicapped person must be retrained to walk and travel, to care for his daily needs, to use normal methods of transportation and ordinary toilet facilities, to apply and remove his own prosthetic devices and to communicate either orally or in writing. These are such simple things that they are frequently overlooked but the personal, vocational and social success of the handicapped person is dependent upon them.

The criteria for discharge from the rehabilitation service is maximum improvement by the patient with regard to training, the vocational objective is not necessarily the Alpha and Omega. If the hemiplegic can be taught ambulation and self-care, he can free a member of his family who can then take on a productive job; or if the patient can be taught self-care and ambulation while still requiring custodial care, the nursing load of the institution can be relieved tremendously.

Rehabilitation is a service tool in the doctor's hands to allow him to provide a program of complete medical care.

It is interesting to see the total problem we are facing. In 1946 accidents were the fourth most important cause of death. Seventy-three of every 100,000 persons met death in this manner in 1945 as compared with the death rate of 321 per 100,000 population for heart disease, 134 for cancer and 86 for cerebral hemorrhage. Although the number of persons killed in accidents was higher by 3 per cent in 1946 than in 1945, the total death rate dropped to 70.8 as a result of the increase in population.

In 1945 the number of working years lost from accidental deaths was 1,750,000, which may be compared with 1,680,000 from heart diseases, 1,110,000 from pneumonia and 1,040,000 from cancer in the same year. In addition to the 99,000 deaths from accidents in 1946, 10,400,000 persons suffered disabling injuries. Of these 370,000 were disabled permanently. The total cost of such deaths and injuries has been estimated by the National Safety Council in its "Accidents Facts 1947 Edition" at nearly $6,500,000,000. Slightly over $1,000,000,000 of this sum may be charged to medical expense and the overhead cost of insurance, $2,500,000,000 to lost wages and the value of lost services, $1,500,000,000 to property damages, and the rest to production delays caused by occupational disasters.

Although great public attention was attracted by such disasters as the Winecoff Hotel fire in Atlanta in December, 1946, in which 119 persons lost their lives, the tenement disaster in New York City during the same month in which thirty-eight persons were killed and the Burlington Railroad wreck at Naperville, Illinois, which claimed the lives of forty-seven persons, such disasters contributed less than 1½ per cent of the total number of accidental deaths in the nation. These disasters, which are classified as catastrophies when five or more persons are killed, accounted for 1,300 deaths in 1946. This was 400 fewer than the year before and was the lowest number since 1941. Similarly, although commercial airline crashes are reported widely, the 1946 passenger death rate for scheduled airlines to 100,000,000 passenger miles was 1.2, the same as the 1939 rate and the lowest on record. It is not the sensational fires, floods, plane crashes and railroad wrecks that make headlines which account for our great number of fatal and disabling accidents, but the steady stream of highway, industrial and home accidents.

INDUSTRIAL ACCIDENTS

Of the apalling number of disabling accidents, some 90,000 each year occur in industrial plants. Added to these are more than 2,000,000 other workers who suffer temporary disabilities from accidents. The total work lost in industrial accidents in 1947 was 280,000,000 man-days or the equivalent of 1,000,000 men kept out of work continuously for more than a year.

Few of these men who are severely disabled have a chance for rehabilitation and the opportunity to return to productive work. In most cases they are retired on disability compensation, physical and psychological cripples, their earning power reduced to nothing and their buying power reduced 50 per cent, unwilling liabilities to themselves, to their families and to the nation.

Added to this tremendous social waste are the direct costs of more than $2,600,000,000 a year in wage loss, expenses for medical care, overhead costs of workmen's compensation, damaged equipment and material, production slowdown, and time lost by fellow workers.

Regardless of their occupation, place of injury or type of disability, injured workers in the United States have one thing in common—the benefits of compulsory workmen's compensation insurance. This is of paramount importance in the problems of traumatic surgery.

At first compulsory workmen's compensation insurance was limited to dangerous enterprises. However, with the growth of modern industry and increased use of power-driven machines in factories and transportation, the danger of accidents and occupational diseases multiplied and it is now universally recognized that an employer is liable for injury to a worker arising out of and in the course of employment, regardless of guilt. When the new Workmen's Compensation Law became effective in Mississippi on January 1, 1949, it meant that all forty-eight states, Puerto Rico and the eight provinces of Canada had such laws. Each act is administered locally, for the United States Workmen's Compensation Law, passed in 1908, applies only to cases involving federal jurisdiction.

Common to all states, an integral part of the workmen's compensation system is the problem of medical care, for no claim can be compensable unless there is competent medical evidence to prove the disability was caused or aggravated

by the occupational injury or disease; nor can disability benefits be granted without a medical examination and report. The importance of medicine in compensation is seen by the fact that doctors and hospitals in New York State alone in 1947 received more than $25,000,000 for services to injured workers in nearly 800,000 reported cases of industrial accidents and disease.

Although medical care has played an increasingly important role in workmen's compensation since the concept of employer liability for injuries to workers was first expressed in Czechslovakia in 1514 and in the Electrorate of Cologne in 1669, the problems of compensation medicine, unfortunately, like those of general medicine, have too frequently been considered purely from the definitive aspect without sufficient regard for rehabilitation, the third phase of medicine, which takes the patient from his bed to the job. In no other phase of medicine, however, does rehabilitation play a more important role. To get the worker back to the job in the shortest possible time, trained to work with what he has left, are the objectives both of rehabilitation and compensation medicine.

Until the advent of World War II, medical care, psychologic problems and the vocational retraining of the disabled worker to the point where he could resume productive work were too frequently considered as separate and distinct processes having little relationship to each other. That they are interdependent and inseparable has been demonstrated by the successful programs in military and veterans' hospitals and has been recognized in civilian rehabilitation by the Barden-LaFollette Amendment which expanded the federal-state vocational rehabilitation programs to include physical restoration, psychiatric services and medical care as well as vocational guidance and training.

Immediately following World War I, as today, there was a developing interest in increasing rehabilitation opportunities for the disabled. Unfortunately, this interest died in most quarters in the years between the wars. However, some pioneer institutions did come from it such as the Institute for the Crippled and Disabled in New York and the Curative Workshop of Milwaukee and Cleveland Rehabilitation Clinic, and some basic legislation such as the Federal Vocational Rehabilitation Act of 1920. The failure of the movement to gain sufficient stature to become an accepted part of medicine, can be attributed to the fact that it was restricted largely to guidance, trade training and the purely vocational aspects of rehabilitation. Few provisions were made for physical restoration or reducing the physical disabilities of the trainees. When the physical condition became static, a program of vocational rehabilitation was planned, "training around" the disability rather than attempting to reduce or eliminate it through medical procedures. In many instances a comparatively large expenditure of time and money was necessary for vocational rehabilitation when, by the expenditure of a few weeks and a more modest sum, the physical limitations could have been substantially reduced with an automatic increase in employment potentials. Such restrictions made it impossible for the state vocational rehabilitation program operating under the Federal Office of Vocational Rehabilitation to give adequate service to their clients. Such failure is shown by the fact that until the basic philosophy of this program was changed by the Barden-LaFollette Act of 1943, in twenty-three years only 210,000 persons were rehabilitated although over a million persons were in need of such aid at any given time during that period.

Rehabilitation under the federal-state vocational rehabilitation programs reached an all-time high in 1948 when 53,131 disabled persons were given services. This represented an increase of 21 per cent or 9,000 clients over the preceding year. Amputations or congenital absence of members constituted the disabilities of 7,276 of the 1948 rehabilitants. Persons with other impairments of limbs as a result of injury or disease numbered 17,042.

Although an increasing number of referrals to the state rehabilitations are coming from physicians, it is ironic that they still constitute only 23.3 per cent of all referrals. Significantly, only 8.9 per cent of all referrals are made from state workmen's compensation agencies and other insurance groups.

Last year the average case cost to state rehabilitation agencies was $460 or approximately the same amount it costs to maintain a person in dependency for one year. Before rehabilitation about 45 per cent of the group were dependent upon their families for support, 8 per cent lived on their insurance benefits, about 8 per cent received public assistance and only 29 per cent were living on their wage earnings.

Since the federal-state vocational rehabilita-

tion program was broadened to include medical services in 1943, 219,039 disabled men and women have been rehabilitated as compared with a total of 210,125 for the preceding twenty-three years. These 219,039 disabled persons have already increased their earnings and the nation's purchasing power by more than $900,000,000. At the same time these persons have since their rehabilitation paid upwards of $67,000,000 into the federal treasury in federal income taxes alone.

Dealing with the specific, the amputee offers a good example that the surgeon must not only do an amputation that is technically sound but also assume the responsibility for preparing his patient physically and psychologically for the amputation and see that the patient has the proper prosthetic device and is trained in its use.

One phase of the management of the amputee to which the traumatic surgeon should give particular attention is the immediate post-operative period while the stump is being shrunk in preparation for a prosthetic device. During this period of six to eight weeks the patient should be given graduated conditioning exercises in preparation for both crutch walking and the later use of the artificial limb. Also, measures should be taken to prevent anatomic deformities. For example, it is not an uncommon practice in many hospitals following an above-knee amputation to elevate the stump upon a pillow. However, if such elevation is maintained for as long as two weeks, a flexion deformity will occur which will take from six to eight weeks of arduous, painful work before sufficient hyperextension can be regained for satisfactory walking.

In advising his patient on the selection of a prosthetic device the physician must be aware of the fact that not all limbs are suitable for all amputees. In fact, he must realize that not all amputees can wear artificial limbs profitably. It has been noted on the rehabilitation service at the New York University College of Medicine that an above-knee amputee in the older age group cannot as a rule be trained profitably to use a prosthesis if he is unable to perform a swing-through gait on crutches.

The physician must point out objectively to the patient those skills which the patient can expect to achieve with proper training and those skills which the patient has little chance of ever regaining. Extreme caution must be taken in the latter, however, as it is unwise to tell a patient what "he cannot do" for this cannot be determined in most cases until the patient has had adequate training. Training is absolutely essential if the amputee is to be successfully rehabilitated.

Regardless of the type of disability the responsibility of the physician to his patient cannot end when the acute injury has been cared for. It ends only when the physician has taken the responsibility for seeing that proper referral has been made to those agencies and institutions which are equipped to rehabilitate and retrain the patient with a residual physical disability. The doctor who fails to see that those patients under his care receive the full benefit of modern methods of medical rehabilitation and retraining is in the same category as the physician who still persists in using dietary restriction alone in the management of diabetes when insulin is available, for medical care is not complete until the patient has been trained to live and work with what he has left.

OSTEO-ARTHRITIS AGGRAVATED BY TRAUMA

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THERE is probably no problem more vexing to industrial surgeons than that concerning the relationship of osteo-arthritis and trauma. It is generally recognized that persons with osteo-arthritis following injury, often of a minor nature, may have undue prolongation of symptoms. However, there is very little in the literature concerning the prevalence of this condition and not much of significance has been written concerning the role in industrial disability of osteo-arthritis that has been aggravated by trauma.

In order to investigate this problem we have, in addition to reviewing the literature, summarized and analyzed eighty-five patients that have been seen by us in the past eight years. An attempt has been made to include in this group only those individuals who have had osteo-arthritis as the cause for prolongation of symptoms. Excluded from the group were those patients who had obvious septic, psychotic or metabolic factors. We have excluded in this analysis those sustaining a fracture, although even in these individuals after a fracture, it is our clinical impression that symptoms may be somewhat prolonged. Thus in this group of eighty-five patients there were only two obvious etiologic factors: trauma and osteo-arthritis. We well realize that this represents a clinical and not pathologic selection for tissue studies are not frequently performed. For obvious reasons no control was possible in this study. We have reviewed the sex, age and occupation of these patients. The mechanism of the injury, part or parts involved, type of therapy employed, ultimate end result, when it could be ascertained, and the degree of permanency have been analyzed. The role of litigation in this group has been determined and, in most instances, we have been able to ascertain the financial involvement. The time lost from work and the number of patients requiring hospitalization have been investigated. We have not excluded any cases in this review of our files of private patients over an eight year period except for the reason that data were very incomplete or the patient was not representative of the problem in question. We are indebted to a number of insurance carriers as well as to many patients for their cooperation in this report.

We have been interested in various aspects of this problem and in analyzing our patients sought to clarify the following questions:

1. What were the usual mechanisms of injury producing this clinical condition?
2. What was the duration of symptoms before these patients were seen?
3. How many were industrial patients?
4. How many had previous symptoms of arthritis?
5. How many required hospitalization?
6. How much time was lost from work as a result of injury superimposed on osteo-arthritis?
7. How many had radiographic evidence of arteriosclerosis?
8. What was the role of body type?
9. What was the financial involvement in the management of these patients?
10. How many were considered clinically cured after treatment?
11. May death result from injury in an osteo-arthritis without the presence of a major fracture?
12. What is the prognosis in an osteo-arthritic who has had an injury?
13. What treatment seemed to be effectual in the management of this syndrome? What has been the scope of therapy?
14. Is an osteo-arthritis that has been aggravated by trauma different from traumatic arthritis?
15. Is the industrial worker of fifty years of age and over an economic liability because of the probable existence of osteo-arthritis which may be aggravated by potential injuries?
16. Is there a common pattern of symptoms and physical findings in patients with osteo-arthritis who have prolonged disability after trauma?
17. Are compensation boards justified in recommending a prolonged financial coverage of patients with osteo-arthritis who have

received injuries and in whom symptoms are prolonged?

In our review of the literature we have found relatively little information on this subject. We have been unable to discover any article in which osteo-arthritis aggravated by trauma has been considered as a clinical entity. However, some years ago Allard[2] in a very stimulating and provocative article reviewed the subject of spinal arthritis in its relationship to industrial disability. He stated that since it was impossible to secure statistical evidence of the part that arthritis plays in this type of disability, one must be satisfied with the presumptive evidence of general opinion. That feeling is still pertinent in the twenty years that have elapsed since his report appeared. He quoted various surgeons who were polled at that time on the relationship of low-back pain to arthritis following injury and recorded the following comments:

"1. Industrial types of back complaints over 3 months' duration, in the absence of fracture, showed in 80 per cent hypertrophic arthritis.

"2. The chronicity of the majority of back injuries is due to the already existing or provoked spinal arthritis.

"3. Arthritis is a highly important factor in disabilities of spine origin.

"4. Nearly 100 per cent of men past middle age who sustained injuries to the spine have some element of arthritis present which greatly prolongs convalescence and places them on the pension roll."

It is to be recalled that these opinions were expressed before recognition of the herniated disc syndrome. One of the industrial commissions that was approached by Allard at that time on this subject replied: "The outstanding feature is that men with arthritis invariably suffer longer disability than those who do not show evidence of disease." That statement is a typical one to be found in various writings.

The conclusions of Allard's studies may well be reviewed and summarized as follows: (1) Arthritis in its various types is a common affliction of adults especially the laborer. (2) Extensive arthritis of the spine (and other joints) may be found without symptoms. (3) Symptomatic arthritis in its incipiency is without roentgen evidence. (4) Arthritic subjects are prone to disability of greater or less duration from injuries that would not affect a normal person. (5) Disability complicated by arthritis occasions a longer convalescence than disability occurring in normal spines. (6) A victim of arthritis is not a normal man. His efficiency is lowered. He is awkward, often distracted by his discomforts, easily fatigued and an easy prey to minor accidents. He is an industrial hazard. (7) Patients with recognized arthritis, properly advised, may be preserved for years of usefulness with big savings to industrial insurance.

Mercer[11] states that the influence of trauma in osteo-arthritis is not sufficiently appreciated. He recalls that all writers are agreed as to the importance of trauma in osteo-arthritis and points out that the injury may be a continuous, chronic, occupational strain or sudden and severe and may have caused a fracture near the affected joint. Injury will serve to determine the onset of arthritis in joints of individuals who have already suffered slightly from generalized arthritis. For example, an injury to a knee or hip is likely to precipitate a troublesome form of arthritis in the injured joint. For this reason, joint injuries in arthritic persons assume an unusual importance and should be prevented or efficiently cared for. While prevention is the first thought, however, the question of how to prevent development of the condition of uncertain etiology, insidious onset and chronic progression is at present beyond solution. The conditions can be treated only as they are found.[2] In considering this problem one must also realize that other factors may play a part in the development and persistence of symptoms. The psychotic personality, postural errors and numerous constitutional causes, such as sepsis, metabolic disorders and, much less frequently, malignant changes must all be considered.

We believe the middle-aged or elderly person who sustains joint injury with prolonged disability in the absence of other definite findings must be considered as having an osteo-arthritis even if the radiographs are normal. Additional x-ray studies after several months may show definite early changes to confirm the clinical impression. This is particularly true in back injuries. Ghormley[4] has pointed out that some types of backache cannot be properly tabulated in any group early in the course of treatment and noted that exact diagnosis might have to await development of definitive radiographic changes.

All are familiar with patients in whom a

joint becomes acutely painful, swollen and red following an injury, and in whom the underlying etiologic factor is a metabolic disorder. In such instances the administration of colchicine and a low purine diet will usually eliminate and control symptoms. Examples of such cases are not included in patients to be presented as these do not truly represent osteo-arthritis aggravated by injury.

Numerous authors have also pointed out that sepsis may cause prolongation of symptoms after injury; and in all patients with an osteo-arthritis following injury, attention must be directed to the elimination of any septic foci—particularly in the teeth, prostate and gastro-intestinal tract. Too often the mild alleged etiologic factor is only an incident while the true cause may be hidden in some constitutional or pathologic condition far removed in another part of the body. This must be sought and found when the patient first presents himself if true diagnosis and proper management of the case are to be logically established.[1] Some of our patients at first considered to be examples of osteo-arthritis aggravated by an injury were found on further study, often after a failure to respond to conservative measures, to have an active focus of infection. Symptoms subside in this type of individual following adequate therapy to the septic factor. We emphasize this point in spite of the efforts of some to minimize the role of foci of infection. We realize that focal infection is not a causative factor in osteo-arthritis. Certainly removal of foci indiscriminately is to be condemned, but a search for focal infection is an accepted procedure in our patients. Congenital anomalies probably play a very small part in the problem as we visualize it.

Arthritis in all of its various manifestations is a common disease of adults. Garvin in a review of about 2,000 radiographs of the spine taken at the Mayo Clinic in subjects over fifty years of age for conditions other than spinal—being mostly of the urinary tract—found that 67 per cent of the men and 40 per cent of the women had hypertrophic arthritis of the spine. The laboring man with spinal arthritis is often in his occupation exposed to danger of accidental disturbance of arthritic adhesions. Often relatively minor accidents such as twists or falls that would not affect the normal spine, produce obstinate disability of varied duration even to permanent incapacity. In osteo-arthritis, hypertrophic bone changes precede the development of symptoms. Very frequently hypertrophic spurs and ridges may reach astonishingly large proportions without producing sufficient disability to cause the patient to discontinue work. Because adaptive adjustments keep pace, distress is thrown on the spine. However, the margin of safety is always reduced. The last-straw factor may break the compensation at any stage in the development of an osteo-arthritic spine.[6] It is well known and should never be overlooked that many individuals have chronic arthritis not only of the spine but of many of the other joints without symptoms. Sooner or later such osteo-arthritic changes will bring on pain and disability regardless of any trauma. An entirely normal motion or stress no greater than has been sustained many times before may become a last-straw factor and pain begins. Industry suffers a severe drain on its manpower from this type of affection since slight trauma may throw on the disabled list for very long periods those whose bodies have been repeatedly insulted by postural errors and the consequent mechanical strain.

The current feeling about the relationship of osteo-arthritis and trauma is that it represents an aggravation of a pre-existing disease by injury and is an industrial injury and not an occupational disease.[5] Of medicolegal interest are some recent decisions handed down which indicate that should disability develop in the worker during the course of his employment even without injury, the case might be considered compensable since the rulings have indicated the effort involved, even though it was not unusual, was at the moment sufficient to constitute an injury. On the basis of these decisions, if upheld, many litigation cases can be anticipated especially if osteo-arthritis is mentioned as a hidden etiologic factor.

One can readily differentiate between rheumatoid arthritis as aggravated by injury and osteo-arthritis aggravated by injury in that in the former the patient has had symptoms prior to development of x-ray changes. In osteo-arthritis well-developed bone lesions are usually apparent before symptoms arise. In rheumatoid arthritis pain practically always precedes development of visible bone changes; in addition, physical stigmata of rheumatoid arthritis are quite characteristic.

In an interesting discussion of trauma and

disease some years ago Moorehead[7] completely ignored the subject of osteo-arthritis in its relationship to trauma. He pointed out that trauma and disease may coexist. He stated that trauma cannot cause disease as a sole factor but that trauma can activate disease. He pointed out that patients can have well advanced disease and be wholly unaware of it, and in this respect his comment is pertinent to the aggravation of osteo-arthritis by injuries.

Lewin[8] has noted that one must differentiate between traumatic arthritis of the spine from trauma to an arthritic spine and trauma to the spine of an arthritic person. Traumatic arthritis is that form of arthritis usually affecting one joint or one part of the body following an injury in which no changes existed prior to the injury, and in which the radiographs and perhaps even the physical findings at a later stage may resemble those of an osteo-arthritis. Traumatic arthritis is seen often in the younger age group. We have frequently observed traumatic arthritis developing in a joint after an injury with a gradual subsidence of symptoms. Months or years later there may be another traumatic insult to the joint, perhaps mild in degree, following which symptoms may again develop and disability may extend over a prolonged period. Examination after the second injury may reveal clinical and radiographic findings similar to those seen after an osteo-arthritis aggravated by trauma since in both the changes are hypertrophic in nature. A history of the first injury serves to clarify these conditions. Therapy may be similar, however, in both instances. In order to show a casual relation between osteo-arthritis and trauma, there must be definite evidence of time, place and degree.

In order that the physician can differentiate between a true primary traumatic arthritis from a non-traumatic arthritis affecting a joint subjected to repeated trauma, certain criteria have been laid down by Morrow.[13] These criteria are important in view of the frequency with which persons seek compensation for alleged traumatic arthritis. They are as follows: (1) The trauma of a specified accident must be severe enough to produce acute inflammation (synovitis) of the affected joint, pain, swelling, effusion and dysfunction. (2) The traumatized joint must be the only one showing such inflammation. (3) It should be established that prior to the alleged injury articular function was normal, but the patient's statement to that effect does not constitute proof thereof. (4) Progressive articular changes may occur and in time be demonstrable clinically and radiographically. These changes should appear within a reasonable limit of time, sometimes within six weeks, generally, within three to six months. When posttraumatic intra-articular osseous changes do occur, they are usually hypertrophic in nature resembling those of an ordinary osteo-arthritis.

Hench[14] has emphasized that lesions produced by acute trauma may be varied. These should not be thoughtlessly lumped under a single term "traumatic arthritis." Ligaments or capsules may be stretched, lacerated or ruptured. Synovial membrane may escape injury or traumatic synovitis develop. Menisci may be displaced, detached, split or torn. Articular cartilage may escape damage or be compressed, split or detached from subchondral bone. Juxta-articular bursae may be the main or only site of trauma. In severe injuries, joints may be dislocated or bones fractured. If one would consider the knee joint, the patient may state that symptoms had developed after a fall on the knee six months previously. Radiographs may show mild, moderately advanced or severe osteo-arthritic changes. Clinically, however, one may readily demonstrate various pathologic components. If fluid is present, there is a synovitis. If the significant physical finding is tenderness over the inner tibial plateau, one is dealing most likely with tibial bursitis as described by Voshell.[23] If a fine crepitation is demonstrated, limited to the patello-femoral compartment especially when flexion and extension are executed with the hip at ninety degrees flexion with the abdomen, one is most likely confronted with a traumatic degenerative fibrillation of the patella. If locking episodes are present, associated with localized tenderness over the joint fissures, meniscus injury is to be considered. Thus although the radiographic diagnosis is an osteo-arthritis the clinical diagnosis may be more exact. In inaccessible joints, particularly in the spine, such careful interpretation of physical findings is not possible.

A few pertinent facts related to posttraumatic osteo-arthritis have been recorded by various writers. Usually there have been pre-existing degenerative changes in cartilage associated with acute trauma. Pathologically there are mechanical changes in the joint, altered weight-

bearing lines and edema of the soft tissues of the joint. The symptoms consist of pain that is aggravated by activity and physical signs include local tenderness, swelling and limitation of motion. Most frequently the knee and lumbar spine are affected. The hip, shoulder, thoracic and cervical spine are next in frequency. Usually this condition is seen in those over forty years of age and is more common in males. It has been stated that the onset in 50 per cent of the patients is sudden after an injury; while in the other 50 per cent, it is gradual after an injury.

In discussing the relationship of trauma to various chronic degenerative diseases the word trauma is employed in a special and definitive sense to mean a sudden, mechanical, external violence at a single occurrence, and not to include repeated or ubiquitous, habitual stresses and strains to which the joints of man are subjected at his daily work.[9]

Pearson in 1928 produced evidence that degenerative changes took place in the posterior root fibers as the result of arteriosclerosis affecting the column of Goll, the ability to perceive vibratory stimuli being thus diminished. It was suggested that the influence of arteriosclerosis in osteo-arthritis is exerted in this way and not directly in the blood supply to the joint which Keefer and Meyers have shown is not affected in proportion to the severity of arthritic changes.[12]

Mechanical injuries frequently elicit neurocirculatory disturbances which are local rather than systemic. The remarkable sensitivity of vasomotor mechanism to local stimuli has long been known. Leriche and his collaborators have been particularly concerned with local reflex vascular reactions to injury. They believe that mechanical stimulation of peripheral nerves may result in the establishment of a state of vasomotor disequilibrium. Occasionally and for no apparent reason a vasomotor disturbance apparently initiated by trauma may persist for a considerable period of time either in the form of a spasm or dilation. The potential importance of neurogenic circulatory disorders, especially following trauma, cannot be denied; but until the methods at the disposal of pathologists are greatly improved, pathologic studies will contribute but little toward their recognition or understanding.[18] It has been suggested that when disability develops in osteo-arthritis there has been an aggravation by metabolic and chemical changes which are taking place and which cannot be described accurately in the light of present knowledge.[9]

In the treatment of osteo-arthritic joints aggravated by trauma in which symptoms have been unduly prolonged we believe that Watkins has eloquently summarized the philosophy of the therapeutic management: "The restoration of compensation or adaptation which has been broken by the last-straw strain may be a long and tedious process. It is an absolute necessity that a program be carefully supervised and intelligently directed in order to permit the re-establishment of an adaptive compensation for the rehabilitation of the worker. The regime aiming at recovery should be as closely supervised and meticulously directed as the "come-back" of a patient with a healing cardiac occlusion or a patient with a healed tuberculosis of the lungs. Rehabilitation for the lower back, for example, so that adaptation and compensation are restored requires time, patience, close supervision and intelligent graduation of selected exercises. No careless instruction to 'go out and do light work' or 'take setting-up exercises' will meet the requirements. The come-back road may be difficult, but success lies at the end. The broad and easy way leads only to failure and disappointment."[6]

It is our belief that when establishment of this syndrome has been recognized, treatment should be based along sound, mechanical lines with the use of principles that have been outlined in many sources for the management of osteo-arthritis. Reassurance is an important preliminary in starting therapy. The patient must be informed that his disability is fundamentally a benign disorder. If coexistent neurotic conflicts and the attendant muscle tension appear to aggravate disability, the resolution of emotional problems and attainment of relaxation may produce striking benefit.[21] Improvement in the general health of the patient, including a loss of weight if obesity exists, is indicated along with the elimination of gravity for a short period of time, particularly in back disability, the development of the musculature on either side of the affected joint by graduated and well outlined exercises, possibly the use of traction, immobilization with exercises, the use of intelligent physical therapy, procaine infiltrations and perhaps even manipulations. The general build and posture of the patient should be considered.

Often in low-back disability attention to footwear, gait, method of standing and walking will often be followed by significant improvement. Many writers have emphasized the importance of the appreciation, explanation and correction of bad body mechanics. "Haphazard mechanical measures and half-hearted medicinal procedures often accomplish very little or no improvement and create discouragement and economic loss on the part of those who are responsible for the care of the patients."[19] The physician may often render invaluable aid in rehabilitation in these patients by approaching employers directly or through the insurance carrier. We have been impressed in a number of instances with the cooperation on the part of the employer in taking the patient back early, perhaps at light work or on part-time, after he has become acquainted with the cause of disability and scope of therapy.

TABLE I
OSTEO-ARTHRITIS AGGRAVATED BY TRAUMA

	No.	Per cent
Males	61	71.8
Females	24	28.2
Age		
30–39 years	1	1.2
40–49 years	6	7.0
50–59 years	36	42.4
60–69 years	30	35.3
70–79 years	11	12.9
80 years and over	1	1.2
Total	85	

TABLE II
OCCUPATIONS

	No.
1. Laborer	38
2. Housewife	19
3. Office clerk	8
4. Salesman	5
5. Farmer	3
6. Truck driver	2
7. Retired	2
8. Miscellaneous	8
Total	85

REVIEW OF CASES

Sex. In our selected series of eighty-five patients in whom an underlying osteo-arthritis had been aggravated by trauma males were more commonly afflicted, the ratio being 7:3. While the pathologic reviews in osteo-arthritis have shown the distribution of histologic changes to be nearly equal in the two sexes, clinical manifestations are stated to be more often seen in females than in males. Since injury is the added factor in our study, it can be readily understood that males would be more often affected especially in an industrial area.

TABLE III
DIAGNOSIS

Part Involved	No.	Per cent	
1. Cervical spine	13	14.3	
2. Dorsal spine	3	3.3	
3. Dorsolumbar spine	5	5.5	33%
4. Lumbosacral spine	22	24.2	
5. Shoulder (acromioclavicular)	10	10.9	
6. Knee	19	20.9	
7. Ankle	5	5.5	
8. Mid-tarsal joints	6	6.6	
9. Hip	2	2.2	
10. Elbow	3	3.3	
11. Wrist	3	3.3	
Total	91		

Age. Two-thirds of all patients in this series were between fifty to seventy years of age. (Table I.)

Occupation. The occupations of these eighty-five patients are tabulated in Table II. Correlation of the scene of injury with the patients' occupations showed that in forty-four patients (52.3 per cent) the occupation was associated with the onset of disability.

Site of Disability. The joint or region that was injured is tabulated in Table III. In five patients more than one part of the body was traumatized and therefore ninety-one different sites were noted involved in eighty-five patients. If the cervical spine is included, we found that disability in this group for the spine was 47.3 per cent. The knee joint was involved second in frequency to the spine (20.9 per cent).

Length of Disability. The length of disability or the period of time that disability had existed prior to the first examination by us is indicated in Table IV. In one-half of the cases studied the injury inaugurating disability had occurred three months or longer before and in one case had extended back eighteen years. Certainly nowhere in the field of trauma does

one find such prolonged disability often out of proportion to extent of the injury. This is especially true when it is recalled that in this series fractures, dislocations, subluxations, sprains, ligament or tendon ruptures and meniscus displacements were not included. If this group is analyzed from the consideration of existing disability prior to examination as being under or over three months, it is found that forty-two patients had symptoms three months or less, the average being 35 weeks. Those whose disability had existed longer than three months, forty-three patients comprising this group, were found to have had an average disability of 2 years.

TABLE IV
LENGTH OF DISABILITY BEFORE EXAMINATION
(Average: 53.8 weeks)

	No.
1–7 days	13
1–2 weeks	5
2–4 weeks	9
1–3 months	15
3–6 months	19
6–12 months	11
1–18 years	13
Total	85

TABLE V
BODY TYPE AND OBESITY

	No.	Per cent
Type:		
1. Asthenic	80	95.3
2. Sthenic	4	
3. Not stated	1	
Total	85	
Obesity:		
1. No	30	
2. Yes	52	61.2
3. Not stated	3	
Total	85	

Body Type and Obesity. Among the contributory factors in the causation of osteo-arthritis, obesity and malposture are stressed. Of all patients in this group. 95.3 per cent were considered to be asthenic in the sense that body mechanics were considered inadequate. Fifty-two patients (61.2 per cent) were obese. These findings were anticipated (Table v)

Previous Similar Trouble. We were interested in the determination of previous similar trouble prior to the stated injury. In approximately one out of five patients (18.8 per cent) there was a record of the patient having had some previous trouble with the involved joint. In most instances the patient minimized the severity and duration of symptoms in the past indicating that present disability was unique for the intensity and prolongation of disability. (Table VI.)

TABLE VI
PREVIOUS SIMILAR TROUBLE

	No.	Per cent
Yes	16	18.8
No	63	74.1
Not stated	6	7.1
Arteriosclerosis		
Yes	9	10.7
No	76	89.3

Arteriosclerosis. Arteriosclerotic changes on radiographic studies were noted in 10.7 per cent of these patients which is probably no higher than might be expected in an unselected group of the same age period. (Table VI.)

TABLE VII
MECHANISM OF INJURY

	No.	Per cent
1. Automobile injuries	18	21.2
2. Falls	38	44.7
3. Struck by heavy object	5	5.9
4. Lifting heavy objects	12	14.1
5. Miscellaneous	12	14.1
Total	85	

Mechanism of Injury. These have been tabulated rather generally as noted in Table VII but it is interesting to observe that over one out of five patients (21.2 per cent) had disability commence as the result of an automobile injury. The number of falls (44.7 per cent) is in keeping with findings reported by other writers who have studied the subject of injuries. One of us (C. R. H.) has reported a study of injuries in childhood in which the chief mechanism of injury in non-fatal accidents was a fall of 32.8 per cent in all patients.

An attempt was made to indicate the intensity of the injury in these patients but it was believed that any division into mild, moderate or severe would be purely arbitrary and not significant. However, in sixteen patients (18.8 per cent) the injury as described by the patient or recorded in the history was considered to be severe.

TABLE VIII
NUMBER HOSPITALIZED

	No.	Per cent
Yes	39	45.9
No	45	52.9
Not stated	1	1.2

Total number of hospital days for those admitted: 412
(Average number of days: 10.6)
Hospitalization extended from 1 to 31 days

Hospitalization. Of these patients 45.9 per cent were hospitalized for treatment. (Table VIII.) The hospital stay was relatively short, averaging 10.6 days. All hospital charts were reviewed and the laboratory studies revealed almost consistently negative or normal findings except for radiographic reports. In many instances it was noted that the patient on his discharge was still having pain. In only a few instances were complete laboratory studies obtained. In correlating the radiographic findings with the physical signs an attempt was made to classify the extent of arthritis in this series. This was difficult because complete x-ray studies were rarely obtained, the affected part only being examined. In general, chiefly on the basis of radiographic studies, it was believed that the osteo-arthritic changes were minimal in twenty-eight cases, moderate in thirty-one and advanced in twenty-six.

Time Lost From Work. The time lost from work after injury in an osteo-arthritic has always been a matter of conjecture. Many insurance carriers find it difficult to accept prolonged disability coverage in patients who sustain a minor injury, especially when they are informed that the radiographs show no fracture about the joint. "Minor arthritic changes" is often the radiographic report of these patients. Table IX is an attempt to show that a great number of patients may be incapacitated for a long period of time after what has been at first considered a minor or negligible injury. Over three months' time from work was lost by 38.8 per cent and 10.6 per cent were not back at work one or more years after the injury. In the fifteen patients (17.6 per cent) who lost no time from work, seven were cases involving litigation. A further breakdown in time lost from work dividing the patients into two groups, those under three months or over three months showed that thirty-one patients lost more than three months, averaging 57.8 weeks. The average time lost under three months in thirty-five patients was 4.1 weeks.

TABLE IX
TIME LOST FROM WORK
(Average: 30.8 weeks)

	No.	Per cent
None	15	17.7
Less than 1 week	1	
1–2 weeks	6	
2–4 weeks	13	
1–3 months	13	
3–6 months	14	
6–12 months	10	
1–2 years	3	
2–3 years	3	
Over 3 years	3	
Not stated	4	
Total	85	

TABLE X
TREATMENTS

	No.	Per cent
1. Physical therapy	50	58.9
2. Appliances (corset, brace, cast, boots, shoes, arches)	41	48.2
3. Medication	33	38.8
4. Procaine infiltrations	27	31.8
5. Bed rest	19	22.4
6. Osteopathic or chiropractic	11	13.0
7. Surgical:	10	11.8
Manipulation—8		
Other —2		
8. Traction	10	11.8
9. Not stated or none	5	5.9
10. Deep therapy	1	1.2

Treatment. Treatments employed in this group of patients are outlined in Table X. Physical therapy in one form or another was employed in fifty patients (58.8 per cent) and

actually was probably used by a still greater number. In many patients a great variety of remedies was employed and it was observed that the greater the prolongation of disability, the more varied the therapy. The use of bed rest for nineteen patients, chiefly with spine

TABLE XI

	No.	Per cent
Compensation	27	31.7
Liability	21	24.7
No litigation	37	43.6
Total	85	100.00

involvement, is in keeping with the thought that elimination of gravity for a period of time, especially if associated with the use of exercises in the prone and supine position, may hasten convalescence. We have found repeatedly that elimination of the influence of gravity in patients with osteo-arthritis of the spine aggravated by trauma is the most important single weapon in the therapeutic approach to this problem. Often pain and stiffness will increase in the first forty-eight hours of complete bed rest, but following this there is a definite cessation of symptoms in most cases to the point that after one week to ten days all symptoms may subside. This occurs usually without the use of physical therapy.

To prevent a recurrence of symptoms when ambulation is permitted, in certain instances plaster immobilization of the trunk is carried out for four to six weeks during which time Bohler's exercises are stressed. Usually by the end of the sixth week such patients do not require further support although a reinforced lumbosacral corset may be advised for an additional three months.

Early ambulation has no place in patients with osteo-arthritis of the spine following an injury that does not produce fractures. This program of bed rest, however, definitely does not involve inactivity. Patients are encouraged and urged to move about in bed from side to side, but the upright posture in sitting and standing is temporarily eliminated.

Conspicious by its absence in the list of treatments employed is the use of occupational therapy. The profession as yet is apparently not aware of the significant role that occupational therapy plays in rehabilitation of osteo-arthritics. Even the diversional phase of such therapy has a profound and favorable psychologic influence in these patients who often suffer a prolonged convalescence. The knowledge acquired by these patients in their association with others who have a delayed convalescence that their problem is not hopeless and that recovery will follow in a well planned therapeutic program gives a lift to the morale that cannot be secured by short weekly visits to an attending physician. Perhaps the fact that many hospitals do not have well-equipped departments or adequately trained personnel in this field of occupational therapy is a factor in the neglect of the use of this important phase of therapeutics.

Attention is directed to the fact that only two open surgical procedures were performed in our series. In one instance a subtrochanteric osteotomy with fusion of the hip was done with a satisfactory end result as far as the patient was concerned; but because of litigation, this man still has not returned to work two years after operation.

Surgical procedures are more often employed in our hands in treatment of traumatic arthritis than in osteo-arthritis aggravated by trauma.

Litigation. An analysis of the role of litigation showed that 56.4 per cent of the patients in this series were either compensation or liability patients. In 43.6 per cent no litigation was involved. (Table XI.)

We were interested in the percentage of patients in each group who were cured, improved or unimproved following treatment. In Table XII a breakdown of these factors is shown. We believe that it is significant that 96 per cent of all compensation patients were either cured or improved. This would indicate that medical supervision of compensation patients in the State of Pennsylvania is adequate. Since we know that disability often extends beyond sixty days, which is the time period designated by the compensation law for medical treatment, it would appear that the insurance carriers accept responsibility of medical supervision in instances of osteo-arthritis aggravated by trauma beyond sixty days. (Table XII.)

The history of previous similar trouble in compensation, liability and non-litigation was investigated; and as shown in Table XIII only 12.5 per cent of patients in whom litigation was involved stated that there had been some pain

or disability in the affected part prior to the present injury. On the other hand 27 per cent of patients in whom no litigation was involved stated that they had previous similar trouble.

While the numbers involved in this analysis are small, it might well be that compensation and liability patients would hesitate mentioning the presence of previous disability for fear of jeopardizing financial coverage of their present illness.

TABLE XII
LIABILITY, COMPENSATION AND NON-LITIGATION

	No.	Per cent
Liability		
Cured	5	23.8
Improved	9	42.8
Unimproved	4	19.1
Not known	3	14.3
Compensation		
Cured	20	74.0
Improved	6	22.0
Unimproved	1	4.0
Non-litigation		
Cured	18	48.7
Improved	17	45.9
Unimproved	1	2.7
Died	1	2.7

TABLE XIII
PREVIOUS SIMILAR TROUBLE
(Yes)

2 (of 27) Compensation	2 Cured
4 (of 21) Liability	2 Improved
	2 Unimproved
(Compensation + liability = 12.5%	
10 (of 37) Non-litigation	5 Cured
	4 Improved
	1 Unimproved
(Non-litigation = 27%)	

End Results. An analysis of our end results showed that forty-three patients (50.6 per cent) were cured. (Table XIV.) In these instances such patients denied any persisting or recurrent symptoms. Thirty-two additional patients (37.6 per cent) considered themselves improved, in many instances considerably so. A number of these patients in another six months or one year would undoubtedly be considered cured. In any event our follow-up examinations indicate that seventy-five (88.2 per cent) of these patients are cured or improved. The one death in the series involved a fifty-nine year old laborer who fell down a flight of stairs at home two days prior to his hospital admission. He was paralyzed below the cervical spine. Radiographic studies showed no fracture or dislocation but did disclose extensive osteo-arthritic changes. He died twenty days after his injury. An autopsy was obtained and the cervical spinal cord found grossly normal. This case was considered typical of a hyperextension injury in the cervical spine without fracture or dislocation, the rigidity of the spine secondary to the osteo-arthritis playing a major role in the final outcome.[20]

TABLE XIV
END RESULTS AND REHABILITATION

	No.	Per cent
End Results		
Cured	43	50.6
Improved	32	37.6
Unimproved	6	7.1
Unknown	3	3.5
Died	1	1.2
Total	85	
Rehabilitated		
Complete	58	68.2
Incomplete	10	11.8
None	11	12.8
Not stated	6	7.1
Total	85	

Degree of Rehabilitation. Fifty-eight (68.2 per cent) of these patients were completely rehabilitated after their injury while an additional ten patients (11.8 per cent) were partly rehabilitated. (Table XIV.) Some patients with residual symptoms classified as improved were able to return to their former occupation. Included in those partially or incompletely rehabilitated were those who stated they miss an occasional day from work or those who had changed their type of work. Among the eleven patients (12.6 per cent) who were not rehabilitated we found three inactive because of litigation; but in each of these patients light work, if available, could have been permitted. Five patients never returned to work because of general debility attendant with their age; one patient had no symptoms referable to her spinal arthritis, but could not work because of a malignant hypertension. One patient was not rehabilitated because of inadequate treatment. The eleventh patient died as noted previously.

Financial Involvement. We were able in 93 per cent of these patients to determine the monetary loss as the result of the injury which inaugurated disability. (Table xv.) It cost $52,390.08 to treat 93 per cent of these people. In one liability case involvement was extremely high; but, unfortunately in this instance, the insurance company did not feel free to disclose the amount of money. The monetary involvement in this group varied from $12.00 to $8,021.00.

TABLE XV
FINANCIAL INVOLVEMENT IN THIS SERIES
(Follow-up—93%)

Compensation	$16,476.43
Liability	$17,209.56
No litigation	$18,704.09
Total	$52,390.08

Certainly it cannot be denied that from an economic standpoint the responsibility involved in the management of these patients is high.

Vehicle Injuries. We have analyzed those patients whose disability started as a result of automobile injuries. In eighteen patients studied eleven had involvement of the spine following an automobile accident. (Table xvi.)

In 61.1 per cent disability following an automobile accident lasted three months or longer. Litigation was involved in seventeen out of eighteen patients analyzed.

The end result and number of patients rehabilitated are shown in Table xvi. Of these patients 61.1 per cent required hospitalization averaging 9.6 days in the hospital.

In fourteen patients who missed time from work as a result of the automobile accident it was found that the lost time period averaged nineteen weeks. The heavy financial involvement of this group, amounting to $16,243.56 for eighteen patients, would indicate that the economic importance of automobile injuries in those of fifty years of age and over may be very substantial. (Table xvi.)

We have reviewed records from the standpoint of the part of body involved. (Tables xvii to xx.) It will be noted that patients with osteo-arthritis of the cervical spine averaged fifty-two weeks in time lost from work, whereas patients with osteo-arthritis of the dorsal and/or lumbar spine averaged 27.2 weeks in time lost from work. Knee involvement in this study showed an average lost time of only 15.6 weeks while shoulder injuries lost on an average of 18 weeks from work. In injuries to the cervical spine every patient was a lost time accident. (Table xix.) It was of interest to note that when litigation is involved it costs substantially more to rehabilitate persons with osteo-arthritis who had sustained an injury. This would be readily accepted by anyone interested in this field but we had been able to demonstrate how much more the financial involvement was in breaking down the patients in this series into small groups. For example, it cost $346.70 on an average to rehabilitate a person with osteo-arthritis of the knee for the group but this amount increased to $506.74 when the case was one of compensation or liability. In the

TABLE XVI
AUTOMOBILE INJURIES

	No.	Per cent
1. Site of Body Involved:		
Cervical spine	6	33.3
Dorsal and lumbar spine	5	27.7
Shoulder	2	11.1
Knee	3	16.7
Elbow	1	5.6
Ankle	1	5.6
2. Length of Disability:		
1–7 days	1	
1–2 weeks	2	
2–4 weeks	2	
1–3 months	2	
3–6 months	7	
6–12 months	1	
Over 1 year	3	
3. Litigation: Yes	16	88.8
Compensation	1	5.6
No	1	5.6
4. End Result:		
Cured	6	33.3
Improved	7	38.9
Unimproved	2	11.1
Unknown	3	16.7
5. Rehabilitated:		
Complete	9	50.0
Imcomplete	5	27.8
Unknown	4	22.2
6. Hospitalized: Yes	11	61.1
No	7	38.9
(106 days, for average of 9.6 days)		
7. Time Lost from Work:		
None	2	
Unknown	2	
Yes (1 week to 28 months)	14	
Average = 19 weeks		
8. Financial:		
Group —$16,243.56		
Average— $1,082.00		
(The amount varied from $80 to $3,280)		

shoulder region the cost of improving or curing the patient was $335.83, whereas in the compensation or liability cases with shoulder involvement the amount averaged $502.93. In the cervical spine $1,151.08 was the average for the group; but it cost roughly $250 more to eliminate disability when litigation was involved ($1,406.33). In osteo-arthritis of the dorsal and/or lumbar spine the average financial involvement for the group of thirty patients was $820.54. If patients in whom litigation was involved were considered apart, the amount was found to be $1,413.25. Thus it can be seen that complete rehabilitation is relatively more expensive in compensation and liability patients as compared to patients in whom no litigation is involved.

TABLE XVII
KNEE INJURIES

	No.	Per cent
1. Litigation: Yes	13	68.4
No	6	31.6
2. End Results:		
Cured	10	52.6
Improved	7	36.8
Unimproved	2	10.6
3. Rehabilitated:		
Complete	15	78.9
Incomplete	3	15.8
Unknown	1	5.3
4. Time Lost from Work:		
None	3	
Yes	16	
Group: 249 weeks		
Average: 15.6 weeks		
Under 1 month—7		
1–28 months—9		
5. Hospitalized: No	12	63.3
Yes	7	36.7
Average: 8.9 days		
6. Financial Involvement: $6,587.60		
Average {$346.70—for the group		
{$506.74—for litigation cases		

4. The mechanism of injury in this type of case showed "falls" to be responsible in 44.7 per cent of the patients, automobile injuries in 21.2 per cent, lifting heavy objects in 14.1 per cent and direct blows by heavy objects in 5.9 per cent.

TABLE XVIII
SHOULDER INJURIES

	No.	Per cent
1. Litigation: Yes	5	62.5
No	3	37.5
2. End Result:		
Cured	3	
Improved	4	
Not stated	1	
3. Rehabilitated:		
Complete	5	
Incomplete	2	
Not stated	1	
4. Time Lost from Work:		
None	3	
2 weeks	1	
2–3 months	2	
11 months	1	
Not stated	1	
5. Hospitalized: No	5	62.5
Yes	3	37.5
Average	11 days	
6. Financial Involvement	$2,686.64	
Average {$335.83—for the group		
{$502.93—for litigation cases		

5. The average duration of symptoms in these patients before being examined by us was 53.8 weeks.

6. Of the eighty-five patients 56.4 per cent had litigation in the form of compensation or liability claims (31.7 per cent were compensation and 24.7 per cent were liability). Of all the patients 43.6 per cent had no litigation mentioned.

7. It was found that 18.8 per cent of the patients studied had had previous similar trouble prior to the injury which initiated the present disability.

8. Hospitalization was carried out in 45.9 per cent of the patients. The average hospital stay was 10.6 days, varying from one to thirty-one days.

9. The average time lost from work in this group was 30.8 weeks. However, fifteen (17.7 per cent) lost no time from work.

10. Radiographic evidence of arteriosclerosis was noted in only 10.7 per cent of the patients.

SUMMARY AND CONCLUSIONS

1. Osteo-arthritis aggravated by trauma should be considered as a distinct clinical syndrome.

2. The literature has been reviewed, attention being directed to the paucity of reports on this subject.

3. An analysis of eighty-five patients with osteo-arthritis who had sustained an injury (major trauma being excluded) is presented.

Our records did not include references clinically on the presence or absence of arteriosclerosis.

11. It was found that 95.3 per cent were considered to have inadequate body mechanics while 61.2 per cent were obese with gradations from slight to marked.

12. The staggering amount of $52,390.08 was involved in the management of these eighty-five patients (93 per cent follow-up).

TABLE XIX
CERVICAL SPINE INJURIES

	No.	Per cent
1. Litigation: Yes	7	58.3
No	5	41.7
2. End Result:		
Cured	2	
Improved	7	
Unimproved	1	
Died	1	
Not stated	1	
3. Rehabilitated:		
Complete	4	
Incomplete	3	
None	4	
Unknown	1	
4. Time Lost from Work:		
Total number of weeks	626 weeks	
Average	52 weeks	
Under 1 month	3	
1–6 months	4	
6–12 months	1	
1–5 years	4	
5. Hospitalized: No	4	33.3
Yes	8	66.7
Average	13 days	
6. Financial Involvement	$11,510.75 (2 not stated)	
Average {$1,151.08—for the group; $1,406.33—for litigation cases}		

13. An analysis of the end results showed that 50.6 per cent of these patients were cured, an additional 36.6 per cent considered themselves improved while only 7.1 per cent were unimproved.

14. There was one death in this series (1.2 per cent), the result of a hyperextension injury to the cervical spine in which advanced osteo-arthritic changes existed.

15. The prognosis in the osteo-arthritic who has sustained an injury is good. A total of 68.2 per cent were completely rehabilitated and an additional 11.8 per cent were partially rehabilitated. Of the eleven patients (12.8 per cent) who were not rehabilitated, it was found that only one had received inadequate medical treatment.

16. Physical therapy is used in the treatment of most of these patients. Open surgical procedures are rarely performed in our hands. In 22.4 per cent the chief therapy employed was bed rest.

TABLE XX
SPINE INJURIES

	No.	Per cent
1. Litigation: Yes	14	46.7
No	16	53.3
2. End Result:		
Cured	19	63.3
Improved	8	26.7
Unimproved	2	6.7
Unknown	1	3.3
3. Rehabilitated:		
Complete	21	70.0
Incomplete	1	3.3
None	6	20.0
Unknown	2	6.7
4. Time Lost from Work:		
None	4	
Not known	3	
Yes	23	(76.7)
Average: 27.2 weeks		
Varied from 1 week to 4½ years		
5. Hospitalized: No	15	50.0
Yes	14	46.7
Unknown	1	3.3
Average hospital period	10.2 days	
6. Financial Involvement:	$21,334.00	
Average {$820.54—for the group; $1,413.25—for litigation cases}		

17. Attention is again directed to the fact that an osteo-arthritis aggravated by trauma is different from traumatic arthritis.

18. Our survey indicates that industrial workers of fifty years of age and over may be economic liabilities in certain instances if their underlying osteo-arthritis is aggravated by injury. Since a control was not possible in this study, it is impossible to state what percentage of workers suffered disability and what the involvement is from the standpoint of time lost and economic loss. It is our impression that adequate therapy instituted promptly and supervised throughout convalescence will definitely increase the per cent of rehabilitation and reduce the time lost from work. Therefore the economic loss sustained should be reduced accordingly.

19. We believe compensation boards and insurance carriers are justified in recommending prolonged financial coverage of patients with osteo-arthritis who have sustained an injury since this combination is notorious for prolonged convalescence.

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INTRA-ARTICULAR LESIONS CAUSED BY FAT PAD HYPERTROPHY

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BIBLIOGRAPHIC research is extremely disappointing with regard to the subject of fat pad hypertrophy (Hoffa's disease) and its relationship to internal derangements of the knee. From the year 1905 to the present time little mention is made of this disease in the literature; although some references use the name in their title, in discussion they fail to be very clear as to the nature of the essential lesion and its complications. From the year 1905 to 1948 there have been approximately thirteen papers devoted to this subject, mostly case reports, indicating either the extinct state of the condition or unwillingness on the part of the surgeon to recognize it in the differential diagnosis of internal derangement of the knee. It may be of course that the condition is so widely known and generally accepted that its introduction at this time is not necessary.

This is a controversial subject and some of our colleagues while denying the fat pad any role in knee joint derangement will agree that on many occasions they have performed arthrotomies and not found the torn meniscus listed as the preoperative diagnosis. After inspection of the joint it was closed and for some reason or other the patient was thereafter relieved of his symptoms. The point is that adequate inspection of the knee cannot be made through the usual menisectomy incision without excising the greater part of the fat pad. One cannot see all the intercondylar notch and anterior crucial ligament and certainly one would not be in a position to rule out a "bucket-handle" tear of the lateral meniscus which as we know may at times simulate very closely a medial lesion. These patients got well because they were sustaining intermittent intrusion of tongue-like projections into the working surface of the joint and excision of the fat pad was the answer.

On January 4, 1904, Albert Hoffa presented his paper on "The Influence of Adipose Tissue with Regard to the Pathology of the Knee Joint" in Berlin, after which his name was associated with enlargement of the subpatellar fat pad and the concomitant synovitis and effusion that so frequently accompany it. This same paper was later read at the Fifty-fifth Annual Meeting of the American Medical Association, September 17, 1904. Originally the first description of disturbance of fatty tissue of the knee was made by Johannes Müller and received the term "Arborescent Lipoma." It was at that time depicted as an exuberant growth of fatty villi sometimes to such an extent that it completely filled the knee joint and caused stretching of the joint capsule. In these early descriptions the lipomas found in the joint varied in size from that of a cherry to a walnut and were generally located on the medial aspect of the knee, with or without a pedicle permitting it to intrude into the working joint surfaces. It was thought that trauma played an important role when elements of the fat pad became impinged. The trauma was responsible for splitting thin synovial layers thus causing escape of subsynovial fatty tissue into the free joint area. Hoffa's first experience with fat pad hypertrophy occurred during an arthrotomy for meniscus detachment. The meniscus was found to be intact and the fat pad to be responsible for the patient's symptoms.

We believe from a study of many microscopic sections of this tissue that fatty hypertrophy is in most instances not a true lipoma but rather an inflammatory hyperplasia. Repeated low-grade traumas will bring it about; and when the thin synovial membrane is ruptured by a single violence or eroded by repeated minor pinchings, the subsynovial fat may exude and thus set the stage for subsequent intrusion and damage to the cartilaginous surfaces. There is nothing to add to the original description of this pad. Its presence is constant in the human knee but its size and contour are not. Like the crucial ligaments it is infra-articular but normally extrasynovial. It is covered by a thin synovial reflection on its inner surface and is attached on the other side to the deeper sur-

face of the patellar tendon. There is no relationship apparent between the size of the fat pad and the amount of general body fat in an individual. The tongue-like projections on the articular side will vary in size and enjoy a considerable range of freedom. (Fig. 1.)

This is a report of fourteen patients with knee joint derangement in which the essential lesion was in the fat pad. The condition varied as follows:

1. *Aborescent Lipoma—Two.* In both cases the amount of fat was great enough to produce severe changes in the articular surface of the patella and underlying femur. In one a patellectomy was necessary and in the other a débridement of the articular cartilaginous surfaces

2. *Anterior Bulge of Hypertrophic Fat—One.* The preoperative diagnosis in this instance was that of ganglion arising from the sheath of the patellar tendon. On inspection of the anterior aspect of the tendon it was found to be normal and was being displaced by a mass beneath it. The tendon was then split longitudinally and the fatty mass exuded. Excision of the greater part of the pad could be accomplished through this exposure.

3. *Femoral Tibial Intrusion of Fat Pad with Cartilaginous Lesions on the Femur or Tibia, or Both—Nine.* These were the patients who had intermittent recurrence of pain, locking and effusion.

4. *Femoral Tibial Intrusion without Any Articular Surface Lesion—Two.* These were the acute cases occurring after torsion violence which could not be distinguished clinically from rupture of the medial meniscus.

Trauma is certainly a factor in the production of this clinical picture although in the case of true aborescent lipoma it probably could not be assigned a role in the production of symptoms. Trauma may be a fall on the knee, sudden jerking or torsion of the knee, producing strangulation of the irregular surfaces between the femur and the tibia. The pain is usually located medially over the joint surface and in acute cases both flexion and extension will be restricted by pain, effusion or hemorrhage. Complete extension will not be obtained even after the acute signs have subsided if a tongue-like projection remains impinged. In older patients quadriceps atrophy will be noted as in many other types of internal derangement. There may be visible swelling in the chronic cases on both sides of the patellar ligament. This swelling will be more prominent nearer the insertion of the tendon on the tibia than its origin on the patella. A pseudofluctuance may be created. The tenderness may not be an important sign after acute inflammation has subsided.

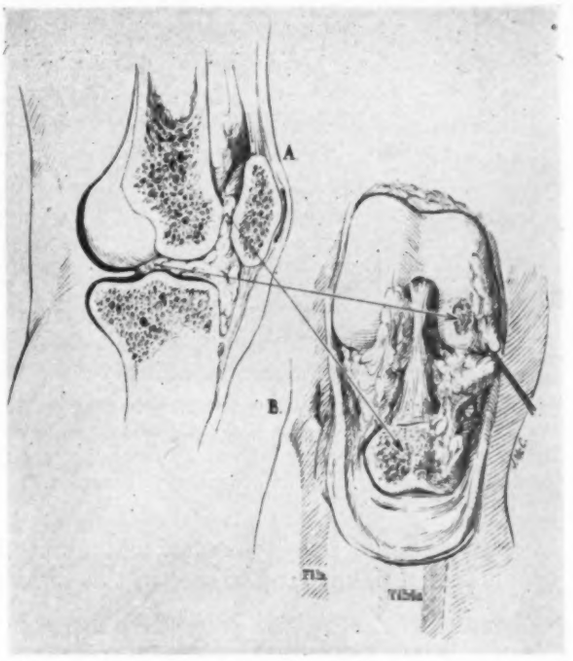

FIG. 1. A, sagittal view of knee showing extension of fat pad between the patella and femur and between the tibia and femur; B, front view showing area of chondromalacia produced by recurrent intrusion of fat pad between articular surfaces.

When the knee is opened, using the usual meniscotomy incision, the fat pad immediately comes into view. If the joint is inspected before the normal relation of the pad is disturbed by retractors, it will be noted that a tongue-like projection intrudes usually between the femoral condyle and the medial portion of the tibial plateau. In recurring cases this tissue may be flattened, grayish white, firmer than normal and at the point of impingement with the knee in complete extension, signs of erosion will be evident on the femoral condyle. This cartilage will be excavated with some undermining of the edges and frequently radial cracks extending from the center. It will be less glistening and duller in color and a débridement of this area can be accomplished through this approach. In acute cases the offending portion of fat may be hyperemic or dark enough to be considered hemorrhagic or even gangrenous as the case may be.

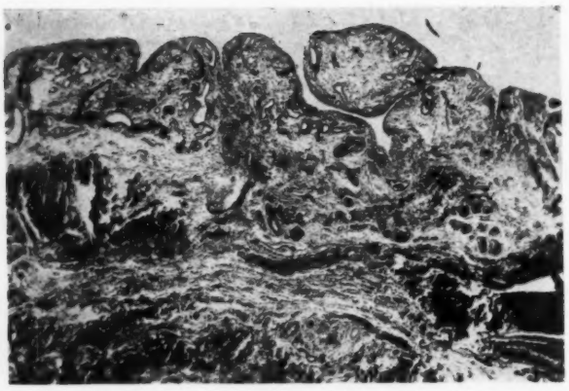

FIG. 2. Increase in papillary formation of synovial surface of fat pad. The subsynovial fat and connective tissue is the site of chronic inflammatory change with increased fibrosis and chromotropic degeneration.

Following are typical examples of acute and chronic lesions of the fat pad seen in this series:

CASE I. L. G., a fifty-five year old white female, 5 feet 4 inches tall, weighing 130 pounds, was admitted to Passavant Memorial Hospital complaining of a painful right knee of three years' duration. The history described an acute onset when the knee "gave way" while she was descending a staircase. No previous trouble with the knee had been experienced. The remainder of the history and general physical examination did not contribute to the diagnosis. On walking she had a definite limp due to inability to straighten the knee completely and her desire to shorten the stance phase of gait as much as possible. There was a slight diffuse effusion throughout the joint and quadriceps bursa but not enough to make the patella ballotable. There was definite tenderness over the medial aspect of the joint surface more anteriorly than laterally. Flexion was limited slightly, probably by effusion of the joint, but extension could not be completed through the final 15 degrees.

Arthrotomy was performed through a menisectomy incision and a moderate amount of blood-tinged fluid exuded. The synovial membrane covering the fat pad was injected everywhere and a tongue-like projection of fat, golden orange in color, with many small areas of hemorrhage and clots scattered over its surface, was found impinged between the medial femoral condyle and tibia. A sub-total excision of the fat pad was done and the medial and central compartments of the knee investigated. No other abnormality could be found. Her postoperative course was uneventful and she has remained well. (Fig. 2.)

CASE II. W. K., a twenty-nine year old white male, 6 feet 2 inches in height, weighing 210 pounds, was admitted to Passavant Memorial Hospital in March, 1947. He told of having injured his left knee twelve years before when he tripped and fell while running a hurdle race. Apparently the injury was a combination of direct violence to the knee on the hurdle and a torsion violence during the fall. He recovered from the episode without any specific treatment but since that time following slight trauma to the knee it would react by pain, swelling and subsequent disability which he believed was out of all proportion to the violence. Two weeks prior to his admission the above triad of symptoms reappeared following a minor twist and the swelling, pain and locking failed to subside following home treatment of rest, heat and protected weight-bearing.

When examined he had a definite limp due to maintenance of the knee in partial flexion. A moderate effusion was present and tenderness was elicited over the medial margin of the patellar tendon and over the anterior aspect of the joint surface. Flexion was limited to 90 degrees and extension to 160 degrees. Neither the x-rays nor remainder of the history and physical examination were helpful.

Arthrotomy of the left knee was performed through the usual menisectomy incision and two tongue-like projections were immediately seen extending from a fat pad which filled the entire intercondylar space to the joint surface between the medial femoral condyle and the tibia. Following removal of the projections and remainder of the fat pad a defect the size of a quarter was seen on the femoral condyle which corresponded exactly to the point of intrusion. Inspection of the joint revealed no other abnormality, his postoperative course was uneventful and he has remained well.

In both these instances the gross and microscopic appearance of the fat and underlying synovial layer corresponded to that described earlier in the paper.

We think this condition of fat pad hypertrophy and intrusion is a definite entity and should be considered in the differential diagnosis of internal derangements of the knee. It is not simply a convenient wastebasket to be used when arthrotomy fails to reveal other causes of derangement. Since the size and shape of the pad varies in individuals, so too the trauma that it sustains will vary as will its response to this trauma. It is of course not easy to make a clearcut diagnosis of this condition preoperatively unless pneumoarthrograms are available, but we have had little experience with this diagnostic measure. There are occasions when this condition may be treated conservatively as minor impingements will respond to rest and heat. The swelling at the point of intrusion will recede and the fat pad will return to normal with minor fibrotic change following.

We have had several such instances; but since they have not been proven at operation, they are not included in this group.

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THE TREATMENT OF AVULSION OF THE COLLATERAL LIGAMENTS OF THE KNEE*

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THE immediate definitive surgical management of rupture or avulsion of the collateral ligaments of the knee is far from established. Immediate surgical repair and conservative treatment by prolonged immobilization are both championed by authority and experience. Boehler's[1] dictum, "Like all other ligaments, those of the knee joint unite satisfactorily if they are retained long enough in good position" is supported by Bristow,[2] Cubbins,[3] and Richman and Barnes.[4] On the other hand Smillie,[5] Abbott and his co-workers,[6] Jones,[7] and Brantigan and Voshell[8] are on the whole in agreement with Palmer of Stockholm[9] who in 1938 stated that, "There is a good chance of operative interference aimed at restitution of the normal anatomic conditions accomplishing complete *restitutio ad integrum*, without lengthening the therapeutic period."

During a fifteen-month period six young men were admitted to the Peter Bent Brigham Hospital shortly after sustaining severe injuries to the collateral and cruciate ligaments of the knee. All were injured in football. In two the forces were so severe as to produce lateral dislocation without nerve or blood vessel injury. Two others sustained avulsion of the medial or tibial collateral ligament together with rupture or sprain of the anterior cruciate ligament and two suffered avulsion of the lateral collateral ligament including the proximal end of the fibula. The basic data on these six patients are presented in Table 1.

CASE REPORTS

The three types of lesions encountered among the six patients and the two methods of treatment employed are described in the following four representative histories:

J. S., (Case 5) a sixteen year old school boy, was struck on the anterior aspect of his right knee while playing sandlot football and was admitted to the hospital forty minutes after the injury. There was gross deformity of the right knee with lateral and posterior displacement of the tibia and fibula on the femur. (Fig. 1.) Peripheral pulses, sensation and muscle function were intact. One hour after admission, under pentothal anesthesia, reduction was easily achieved and the extremity was immobilized in a well padded plaster cylinder from the groin to the toes with the knee in moderate flexion. One week later a lightly-padded plaster of paris spica was applied. The patient was discharged from the hospital twenty-four days after admission and resumed his classes seventy-one days after injury. The plaster cast was removed six weeks after application, crutches were discarded at three months and full activity was resumed two months later.

The result sixteen months after injury was satisfactory but not perfect. There was no atrophy and surprisingly little anteroposterior mobility of the tibia on the femur. There was approximately 10 degrees of lateral laxity of the extended knee but flexion was possible only 100 degrees from full extension.

This patient was fortunate in that he suffered no neurovascular injury and apparently no internal derangement. His disability, however, was prolonged and it appears unlikely that he will ever regain full flexion of the injured knee.

V. M., (Case 6) a twenty-five year old college fullback, while running on the offense was struck on the posterior lateral aspect of his flexed left knee (Fig. 2) sustaining a complete lateral dislocation. The tibia and fibula were rotated externally approximately 90 degrees on the intact lateral collateral ligament. The patella was dislocated laterally. Peripheral pulses and motion of the toes and ankle were normal. Within one minute of injury, on the playing field, reduction was very easily effected with almost no discomfort. A sponge rubber compression bandage was applied as well as a well padded plaster of paris cylinder from the toes to the groin with the knee in moderate flexion. Four days later the medial aspect of the knee was exposed through a long curved incision. (Fig. 3.) The medial collateral ligament was found detached from its tibial attachment and lay transversely within the joint, its distal end in the intercondylar notch. Both cruciate ligaments were ruptured at

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TABLE 1

KNEE LIGAMENT AVULSION

Case No.	Patient	Age	Injury	Treatment		Disability			Result				
				Immediate	Definitive	Hospitalization (days)	Resumed Classes or Work (days)	Full Activity (weeks)	Time (Mo.)	Range of Motion	Atrophy	Lateral Laxity	Antero-posterior Laxity
1	W. T.	24	Lateral avulsion anterior cruciate sprain	Splint	Exploration and suture 20 hr. after injury	10	12	16	14	Normal	0	0	0
2	J. W.	22	Lateral avulsion anterior cruciate sprain	Splint	Exploration and suture 4 hr. after injury	5	10	8	2½	Normal	¾ in.	Slight	Slight
3	R. M.	21	Medial avulsion anterior cruciate rupture	Plaster cylinder	Exploration and suture 6 days after injury	20	21	11	3¼	Normal	0	0	Moderate
4	W. G.	23	Medial avulsion	Plaster cylinder	Exploration and suture 3 days after injury	14	120	20	14	Normal	0	Slight	Slight
5	J. S.	16	Lateral dislocation	Reduction 40 min. after injury; application plaster cylinder	Immobilization in plaster spica 8 days after injury	24	71	20	16	180°–75°	0	5°–10°	0
6	V. M.	26	Lateral dislocation	Immediate reduction one minute after injury	Exploration; removal medial meniscus; suture 4 days after injury	15	16	16	4	Normal	0	Slight	Moderate

FIG. 1. Anteroposterior roentgenogram of right knee prior to reduction. Case 1.

their proximal ends. The medial meniscus was displaced to a vertical position in the intercondylar notch. The meniscus was removed, the torn ends of the cruciate ligaments approximated and the distal end of the avulsed lateral collateral ligament sutured in place beneath the pes anserinus. Fine, interrupted cotton sutures were used throughout. Carefully supervised active motion was started on the eighth postoperative day. The patient was discharged from the hospital fifteen days after his injury and resumed his classes the next day. Crutches were discarded thirty days after injury and full activity was resumed three months later.

The end result at fifteen months was very satisfactory. The range of motion was normal, there was no atrophy, lateral laxity was less than 10 degrees and there was only slight anteroposterior laxity. Four months after injury the patient was able to participate in college track and baseball without difficulty.

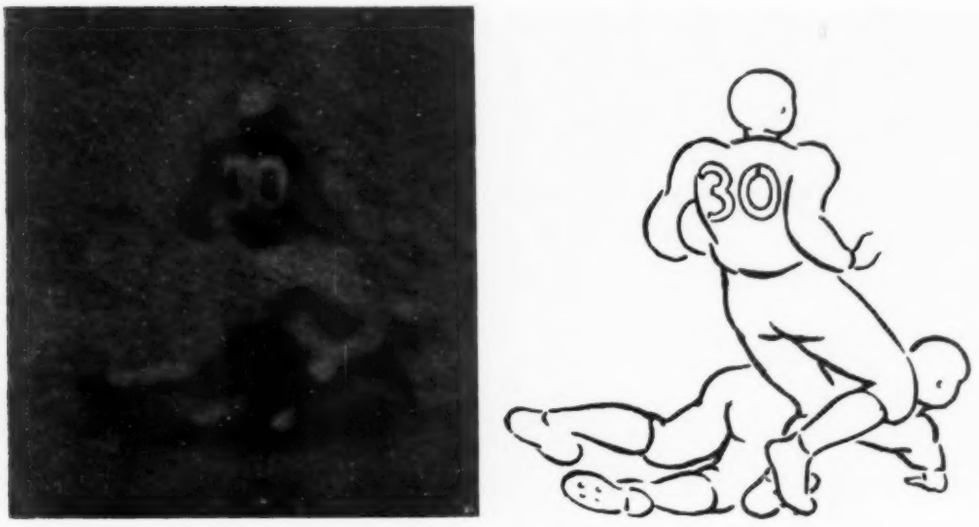
W. T., (Case 1) aged twenty-four, was struck on the posterior aspect of his flexed right knee while playing in the backfield on offense in intramural college football. X-rays taken immediately after the accident disclosed avulsion of the proximal end of the fibula (Fig. 4) and the extended knee could easily be adducted approximately 15 degrees from its normal position. The peroneal nerve was intact. At operation the morning after injury the lateral aspect of the joint was exposed. (Fig. 5.) The anterior cruciate ligament was stretched but was in continuity. The lateral meniscus and the anteromedial portion of the medial meniscus were intact. The avulsed fragment of the fibula was replaced and held with interrupted mattress sutures and the adjacent capsular rent was approximated with fine interrupted cotton. The patient was discharged from the hospital ten days after admission and resumed his classes the next day. All splints were removed thirty days after injury, crutches were discarded twelve days later and full activity was resumed at four months.

Fourteen months after injury the knee was apparently normal without atrophy, limitation of motion or lateral or anteroposterior laxity. Approximately the same result was obtained in another very similar case in which the patient was operated upon four hours after injury (Case 3, Table 1).

R. M., (Case 3) a twenty-one year old college undergraduate, while carrying the ball in an intramural football game, suddenly changed direction twisting to the right. His right foot was fixed to the soft ground by cleats. There was immediate pain on the medial aspect of the knee and examination a few moments after the injury disclosed almost no resistance to approximately 15 degree abduction of the extended knee. (Fig. 6.) Six days after the injury the medial aspect of the joint was exposed. The medial collateral ligament was avulsed from its tibial attachment and a transverse tear into the joint extended from the medial collateral ligament to the patella. The anterior cruciate ligament was ruptured in its upper portion. The menisci were intact. (Fig. 7.) The ends of the cruciate ligament were approximated and the tibial collateral ligament replaced beneath the pes anserinus. The patient was discharged from the hospital twenty days after his injury and resumed classes the next day. All splints were removed five days later and crutches were discarded thirty days after injury. Full activity was resumed at eleven weeks.

When examined six months later the knee was almost indistinguishable in appearance and function from its fellow. Range of motion was normal; there was no atrophy or lateral laxity and only slightly more anteroposterior mobility than normal.

In a similar case (Case 4, Table 1) disability was apparently prolonged, full activity being resumed five months after injury. However, the patient was a printer and could not return to work until he could stand for a full working day.



2A 2B

FIG. 2. An enlargement from motion picture film showing the injury which produced dislocation of the left knee. The patient wears the numerals 30 on his jersey; B, drawing made from motion picture film. Case 2.

COMMENT

Diagnosis. In the present series it was possible to examine every patient within a few moments of injury. Determination of abnormal mobility could be made with assurance and little or no discomfort. In patients seen hours or days after injury edema and muscle spasm can make examination difficult and uncertain. Moore,[10] Abbott and his colleagues[6] and Hitchcock,[11] have advised aspiration, manipulation and roentgen examination under anesthesia. The latter recommends this procedure for every knee injury in which marked effusion occurs immediately after injury. In none of the present series was effusion present and it is assumed that blood and joint fluid escaped through the rents in the capsule which were demonstrated in every case. It would therefore seem reasonable to reserve diagnostic manipulation under anesthesia for severe knee injuries, particularly those which do not exhibit effusion but instead present the boggy, diffuse, subcutaneous edema which developed in those patients in the present series in whom operation was delayed.

Whether an accurate diagnosis is made immediately after the injury or later, 15 degrees of abduction or adduction of the extended tibia on the femur can be considered diagnostic of separation of the collateral ligament and rupture or stretching of the anterior cruciate ligament. This has been established by the experimental and clinical work of Palmer,[9] Brantigan and Voshell,[8] and Abbott and his co-workers.[6]

Treatment. Satisfactory results have long been known to follow prolonged immobilization in a considerable proportion of patients. However, precise surgical restoration of continuity is always to be preferred when it can be achieved. The risks of operation are slight and the advantages to be gained are considerable. In a certain proportion of patients the avulsed ligament may lie within the joint as Palmer,[9]

FIG. 3. Medial exposure of left knee four days after injury; the joint is held in valgus. The avulsed medial collateral ligament has been withdrawn from the joint and the meniscus from the intercondylar notch. A suture has been inserted into the ends of the anterior cruciate ligament. Case 2.

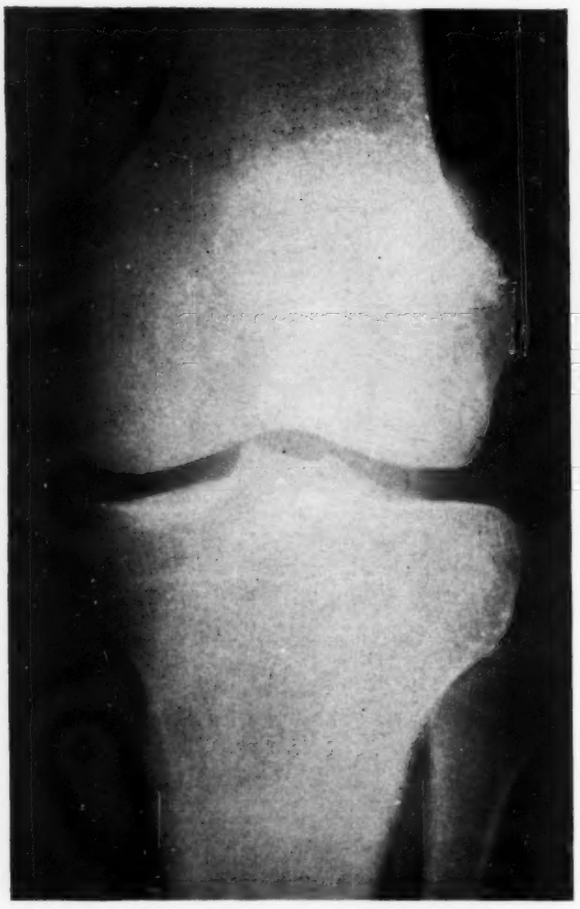


FIG. 4. Avulsion of the proximal end of the right fibula. Case 3.

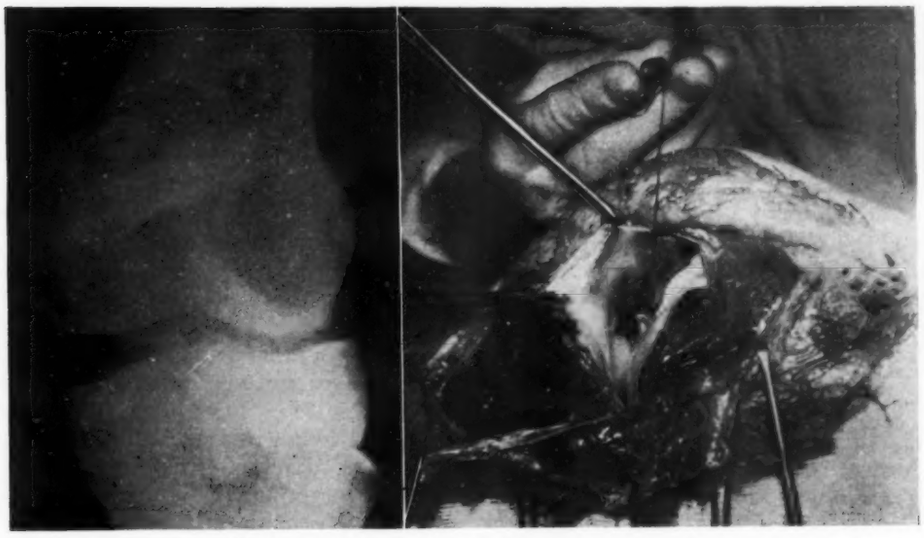
Smillie[5] and others have pointed out and as was the case in the second patient of the present series. This situation cannot always be determined by examination alone. Also, in a certain number of cases displacement or another injury to the menisci may have occurred. Hulten[12] found separation of the meniscus from its medial attachments in 13 per cent of his abduction experiments on cadavers.

The disposition of the injured anterior cruciate ligament is a matter of considerable debate. The experience of the Harvard Athletic Association[13] has been in agreement with that of Darrach[14] who believed that formal operative restoration of these ligaments was not necessary. The knee can be considered as a physiologic unit. The loss of one of its components is not serious and if this component is the anterior cruciate ligament it is even insignificant provided that the musculature of the knee is normal. This is merely a restatement of Sir Arthur Keith's "Law of

FIG. 5. Lateral aspect of right knee at operation; an instrument indicates the fracture face of the proximal fragment of the fibula. Case 3.

Ligament."[15] The ruptured anterior cruciate ligament was approximated twice in the present series (Cases 2 and 6) but this was not done with any thought of restoring its original length or strength but rather to establish continuity so that the ragged ends would not serve as a future source of internal derangement. In all of the patients of the present series an active vigorous program of exercises was instituted at the earliest possible moment and continued to the point of maximum improvement. Exercises of the resistance type recently described by deLorme and Watkins[16] were employed.

Dislocations. Fortunately neither of the two dislocations of the series suffered nerve or blood vessel injury. Interruption of the vascular supply to the leg accompanying dislocation at the knee must take the highest priority in treatment. Reduction of the dislocation must be carried out at the earliest possible moment.[17] If restoration of arterial supply does not follow reduction, exploration of the popliteal space, inspection of the damaged segment of artery and, if necessary, excision or replacement by a vein graft should be carried out at once followed by lumbar sympathectomy and heparinization. The experience of the two world wars with regard to injuries to popliteal arteries is discouraging[18–21] and only by such vigorous measures can gangrene be averted. When arterial supply to the leg is intact after reduction, early exploration and repair of the avulsed ligament must be regarded as the treatment of choice. The contrast between the



6 7

FIG. 6. Roentgenogram of right knee in abduction prior to operation. Case 4.
FIG. 7. Medial aspect of right knee at operation; the avulsed medial collateral ligament is seen in the lower left. A suture has been inserted into the proximal end of the ruptured anterior cruciate ligament. Case 4.

two dislocations in the present series from the point of view of disability, both in time and eventual degree, is striking.

The satisfactory end result achieved by conservative therapy in Case 1 must be regarded as fortuitous in view of the extensive intra-articular derangement disclosed at operation in Case 2.

SUMMARY

1. Six cases of avulsion of the collateral ligaments of the knee including two lateral dislocations are presented.

2. In five cases early exploration and suture of the avulsed ligaments were carried out with prompt restoration of function and minimal permanent disability.

3. Conservative treatment of one dislocation by prolonged immobilization in plaster after reduction resulted in loss of full flexion of the knee.

4. Diagnostic manipulation under anesthesia is recommended for severe knee injuries, particularly those which do not exhibit effusion.

5. Complete collateral ligament avulsions should be explored and repaired within a few days of injury. The procedure carries little risk, establishes the diagnosis with precision and lessens disability both in time and degree.

6. Obvious dislocation of the knee should be reduced at the earliest possible moment. Associated injury to the popliteal artery takes the highest priority in treatment and exposure with resection or replacement of the damaged vessel should not be delayed.

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DISCUSSION OF PAPERS BY DRS. HANLON AND ESTES, STACK AND CHASTEN, AND QUIGLEY

W. L. Estes, Jr. (Bethlehem, Pa.): I have very little to add to Dr. Hanlon's presentation. This was largely his investigation and his work. However, there are three or four points which I would like to emphasize.

His report concerns trauma to the joint which is involved in osteo-arthritis and not trauma simply to an individual who has osteo-arthritis elsewhere than the traumatized area.

Secondly, the disability in this series was found due largely to the presence of osteo-arthritis rather than specifically to the trauma. The major portion of the disability arose from the fact that the individual injured had osteo-arthritis rather than the severity of the trauma; that is, only those cases which were involved in the mild trauma have been studied. It is possible that a further report will consider the problem of major trauma such as fracture or dislocation in association with osteo-arthritis.

Finally, I think we might summarize this report as follows:

(1) Osteo-arthritis aggravated by trauma should be considered as a distinct clinical problem; (2) the mechanism of injury indicated that falls were responsible in about 44 per cent of the cases, automobile injuries in 21, lifting heavy objects in 14 and direct blows in about 6; (3) the average duration of symptoms in these patients when applying for treatment was approximately one year; 80 to 86 per cent were cured indicating that even after a considerable interval following the trauma with persistent disability, rehabilitation should not only be undertaken but is still quite possible; (4) 56 per cent of the patients had litigation in the form of compensation or liability claims; (5) the average time lost from work in this group was approximately thirty weeks; (6) it was found that 95 per cent were considered to have inadequate body mechanics.

Kellogg Speed (Chicago, Ill.): I wish to say a few things about Dr. Stack's paper which is an excellent plea for arthrotomy on the knee for wide exploration in any suspected case of internal derangement. There is great difficulty in diagnosing an isolated catching or tearing of the fat pad in comparison to cartilage or other injuries because the x-ray will be of no assistance. It takes clinical experience and horse sense and perhaps a thorough understanding of the anatomy which he outlined for us even to presume on such a diagnosis.

I have found this fat lesion, as you all have, a great many times, often combined with the cartilage avulsion or injury. It is not always necessary to remove the cartilage; that would depend on how loose it is. But the fat pad may be widely cut away and removed without any fear of resulting difficulty. I have done it over a hundred times in various arthrotomies on the knee joint. Even when a constrictor is used on the leg and there will be hemorrhage into the joint after the fat is removed, one does not hesitate to perform a proper resection.

In isolated findings of fat pad injury I have found them ecchymotic and even dripping with blood without any other lesion in the knee joint and, also, as greatly prolonged or pedunculated masses, waggling free in the joint and caught between the articulating surfaces as Dr. Stack mentioned.

Occasionally they are adherent to the intercondyloid notch or the cruciate ligaments and drawn out by that adherence.

Finally, I do not believe that they are the cause of malacia of the joint or of the articular surface of the patella. I think they are secondary to the general change in the joint or the cartilaginous change in an osteochondritis and that they are somewhat in the nature of the pannus that forms on the eye in cases of irritation or foreign body near the limbus or in the cornea. That adherence and attachment and extension of the fat pad may bring capillary vessel attachment to the changes in the knee joint.

Wilbert H. McGaw (Cleveland, O.): It was a pleasure to hear Dr. Stack's presentation and I agree with him that real pathologic changes do occur in the fat pad. We have found four main types of fat pad lesions: (1) This type is the most common and involves an increase in size and consistency and is usually associated with areas of fibrosis which seem to be the seat of repeated traumatic pinching. (2) The lower edge of the fat pad becomes adherent to the anterior cornu of the medial meniscus. I believe that this type is more likely to occur in so-called hypermobile menisci. These patients obtain complete relief with removal of a portion of the fat pad and the anterior portion

of the meniscus. (3) The third type of change we have found in cases in which a fragment of bone or cartilage has become adherent to the fat pad. These pieces of bone, such as are produced in osteochrondritis dissecans, may cause thickening, fibrosis and adhesions in the anterior part of the joint. A portion of the fat pad must be removed to excise some of these fragments. (4) The fourth type is the seat of acute trauma showing laceration of the synovia with a hematoma filling all or part of the fat pad. Although the fat pad is well protected, a direct blow such as falling on the edge of a stair can easily produce a direct contusion to the fat pad which in turn produces swelling and bleeding. The ligamentum mucosum likewise can be torn by a direct blow.

Dr. Quigley deserves commendation for his excellent paper on the treatment of collateral ligament injuries. The early surgical repair following an accurate diagnosis undoubtedly affords the best early results in acute ligament injuries.

HARRISON L. MCLAUGHLIN (New York, N.Y.): I would like to speak briefly about Dr. Quigley's paper which was very informative and well documented.

I think it would be even more informative if he would state his principles of management of borderline cases. I would like to know what he would do (1) in the presence of less than 15 degrees of instability and (2) in the presence of bilateral collateral tears, assuming the essential circulation was intact.

One must commend him for his philosophy of management of the anterior cruciate tears. This ligament has been accorded much more functional importance than the clinical experiences of most surgeons warrant. As far as I know, no patient on our service has had an anterior cruciate repair except for the purpose outlined by Dr. Quigley, that is, to prevent the loose ends from becoming caught between the bones to produce subsequent internal derangement. A great many more have been excised than have been repaired and I think it is safe to state that follow-up results have failed completely to indicate or allow any identification of the presence of instability or dysfunction in knees with known absences of the ligament.

I would like to emphasize one point that Dr. Quigley did not. Some months ago I had the opportunity of seeing the patients on whom he has reported. Rarely have I ever seen a more satisfied or, from a surgical viewpoint, a more satisfying, group of results.

C. R. HANLON (closing): It was impossible to cover what we had developed in our study. In a 93 per cent follow-up we found that it cost $52,306 to control and treat these patients. If it cost that much to treat eighty-five patients, on the basis of 150 million people in this country we might estimate that it would cost 92 billion dollars a year for the Government to take over.

JAMES K. STACK (closing): I wish to thank the doctors for discussing the paper and I want to assure Dr. Speed that I did not mean for a moment to leave the impression that these cases had been diagnosed preoperatively because they were not. Our percentage was very poor. Practically all of the patients were operated on either for acute tears of the normal meniscus or with the thought that there was something wrong with a degenerated meniscus in the older group of people.

The point you and Dr. McGaw brought out about the microscopic changes that take place in the pad is, of course, true. We did not have time to go into that during the formal presentation.

T. B. QUIGLEY (closing): I should like to thank Dr. McLaughlin for his, as always, penetrating questions.

As to the borderline case, for the past four years we have been trying to make some sense out of sprains which we see in considerable number. We try to grade them on a basis of I to IV, I being the least degree of injury to a ligament which one can conscientiously call a sprain and IV being complete avulsion.

Now, would we operate on patients with grade III sprains? I think we might be tempted to do so. In none of the patients in the present series was there any doubt about the fact that they had grade IV sprains or complete avulsions. I think if there were a doubt as to whether or not an arthrotomy or an exploration were indicated, examination under anesthesia with x-rays available and preparations to go ahead with exploration if indicated is in order.

As was stated, 15 degrees of abduction or adduction is established as the critical level of rupture of either collateral ligament and the anterior cruciate.

As for bilateral tears, I have never seen one. They must be very rare. In perusing the literature on this subject during recent months I came across no cases. Should such a case appear, I am certain that the greatest priority in treatment would be the neurovascular situation. Granted that is intact, I believe that both sides of that knee should be repaired.

OPERATIVE TECHNIC FOR CALCIFIED TENDONS ABOUT THE SHOULDER JOINT

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CALCIFIED tendinitis and its secondary subacromial bursitis are very common conditions. In the past there has been a tendency to call all cases subdeltoid bursitis and treat them as such. Other cases that we have seen classed and treated as "bursitis" are: acromioclavicular arthritis, tuberculosis, tenosynovitis of the long head of the biceps, capsular tears, bone islands in the head of the humerus partial paralysis of the serratus anterior muscle, radiculitis and caisson disease. (Figs. 1, 2 and 3.)

FIG. 1. Case of tuberculosis of shoulder treated for many years for bursitis. Note large cystic areas in head of humerus and narrowing of shoulder joint.

We believe that with a consideration of the anatomy of the shoulder, a study of the symptoms, a careful physical examination and proper x-rays an accurate differential diagnosis of shoulder conditions can be made; and if a case is one of calcified tendinitis, one can definitely determine the location and condition of the calcium deposits and their relation to and condition of the bursa. If these facts are known, the proper treatment may be selected.

FIG. 2. Shoulder with symptoms and an unrelated bone island mistaken for calcium deposit.

Some patients will get well untreated,[1] some respond to simple procedures and some will not get well until given surgical relief.

SURGICAL ANATOMY

To understand the pathologic changes and symptoms produced by calcified tendinitis and subacromial bursitis, it is necessary to recall that the capsule of the shoulder joint in its superior and posterior portions blends with the flat expanded tendons of the supraspinatus, infraspinatus and teres minor muscles as they pass to their insertions on the greater tuberosity of the humerus.[2] The subscapularis muscle differs from these muscles by being separated from the capsule by a large subscapular bursa. This bursa usually connects with the shoulder joint. We thus rarely see a calcium deposit in this bursa. The long tendon of the biceps muscle is invested by a fold of joint synovia which is carried in the form of a tubular prolongation into the intertubercular sulcus and ends blindly opposite the insertion of the pectoralis major muscle.[2] We have not seen calcific deposits in this sheath but teno-

FIG. 3. A case of severe acromioclavicular arthritis previously treated as bursitis.

synovitis occurs not infrequently. The supraspinatus tendon lies above and forms the roof of the shoulder joint. It also forms a good part of the floor of the subacromial bursa. This, one of the largest bursae in the body, extends further downward between the deltoid muscle and the greater tuberosity and on upward under the acromium and the coraco-acromial ligament. (Fig. 4.) The bursa tends to disappear under the acromium when the arm is abducted.

One can readily believe that a heaped up calcified deposit in one of the capsular tendons may well encroach on the floor of the bursa and interfere with motion. Furthermore, when the calcium in the tendon ruptures, it usually passes into the bursa. We have seen it break through into the shoulder joint but such instances are exceedingly rare. If the supraspinatus tendon is completely divided, the shoulder joint and bursal sac become one continuous cavity. In such a case there will probably be no calcific deposit in the torn tendon.

ETIOLOGY

We do not definitely know what causes calcified deposits in tendons. They have been considered as being laid down in an attempt to repair a degenerative process, to repair multiple small tendon tears and as a part of some metabolic process. Codman believes that trauma is the most likely.[3] Wilson leans toward the degenerative theory.[4] Not so uncertain is the sequence of events in subacromial bursitis. Barring the very rare primary, distended, non-calcified subacromial bursa and the rare suppurative type,[5] the ones we commonly see are produced as follows:

The calcium is deposited in the tendon. It heaps up as a soft toothpaste-like substance or hard mass. It may lie quiescent a long time but sooner or later nearly all such deposits act like foreign bodies and as they are rotated under the bursa the latter becomes inflamed.

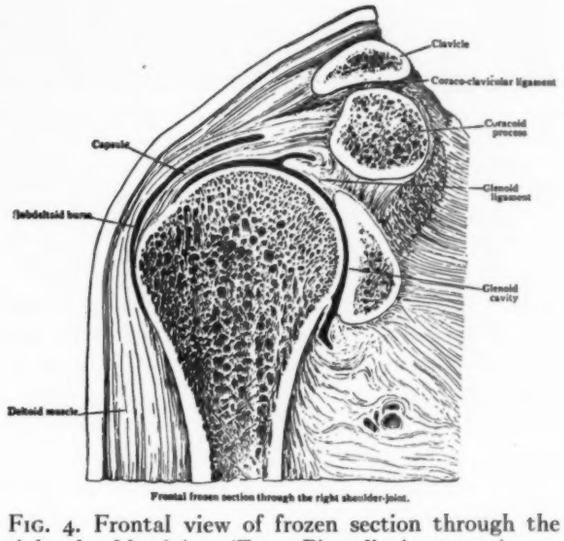

FIG. 4. Frontal view of frozen section through the right shoulder joint. (From Piersol's Anatomy.)

Also when the shoulder is abducted, the bursa becomes pinched between the acromium and the calcific mass, liquifaction or softening of the calcium takes place—this causes distention—and finally the deposit usually breaks through into the bursa. It may be absorbed but, if not, the bursa becomes inflamed to varying degrees. There is pain and disability and the patient seeks medical advice. There is usually no history of a specific trauma; the shoulder just begins to ache.

We divide the patients into chronic, subacute and acute types.

SYMPTOMS

The chronic patient has had an intermittently aching shoulder over a period of months or years. Due to spasm of the neck muscles pain may radiate up the side of his neck or it may go down the arm toward the insertion of the deltoid muscle.

The subacute patient is one with a chronic case who has interval flare-ups following unusual exercise. He gets discouraged when he trys to play tennis or golf. He cannot sleep on the affected side.

The acute case occurs when the patient has such an extremely painful shoulder that he

FIG. 5. Soft deposit at time of acute symptoms and six weeks later; patient had no treatment. These soft deposits will clear up without treatment more quickly with irrigation, x-ray irradiation or diathermy. However, removal by surgery is the most specific form of treatment.

FIG. 6. Case of mixed soft and hard deposits, the large, soft deposit being in the supraspinatus tendon and the small, hard deposit in the terres minor tendon. These mixed deposits are always best treated by surgery.

cannot move it. He is unable to sleep except with heavy sedation. He walks the floor and he has pain in the arm similar to pain of an abscessed tooth.

PHYSICAL EXAMINATION

The chronic patient has limitation of rotation especially when the shoulder is at the same time held in abduction. There is point soreness over the calcific deposit. There is usually atrophy of the supraspinatus and especially of the deltoid. There may be localized swelling visible and palpable.

In the subacute patient motions in the shoulder are restricted in accordance with previous usage and activity. There is point tenderness over the calcified areas.

The acute patient holds his arm to his side. His axilla is wet with perspiration. His elbow is flexed. All motions are painful. There is exquisite tenderness over the bursal area.

X-RAYS

We seldom see ideal roentgenologic views. The shoulder is painful and the technician does not know how to take required views without hurting the patient. He therefore gives us poor films. However, proper and adequate films can be taken and the arm and shoulder not moved if the technic of Raymond Lewis is used. Lewis makes roentgen ray studies of the aching shoulder by leaving the arm and shoulder in a sling, letting the patient stand or sit and rotating the patient's body, rather than the shoulder, to get the desired projections.[6] If proper films are not available, proper evaluation of the case and appropriate treatment cannot be rendered. (1) The chronic patient has a hard fixed deposit in one or more tendons. (2) The subacute patient may have a soft deposit which is irregular, mottled and he may have one or more hard deposits also. (3) The acute patient reveals a cloudy diffuse shadow in or under the bursa and rarely in the shoulder joint. There may also be other hard or soft unruptured deposits.

TREATMENT

One clinic will treat most patients with x-ray irradiation, another with various forms of heat and diathermy, another will use intramuscular drugs. Rest, sling and sedatives will relieve many. All of these forms of treatment are particularly adaptable to subacute and acute types. Patients thus benefitted usually have one large soft deposit superficially placed in a tendon, or already ruptured into the bursa. (Fig. 5.) Likewise such patients may be treated by aspiration and irrigation with the two needle technic.[1,7,8] We still find that this offers dramatic relief to the acute shoulder.

We believe that operative treatment is indicated in all patients with unruptured single or multiple hard deposits and in all cases with mixed hard and soft deposits. (Fig. 6.) Surgery for the single soft deposit is specific but as indicated above other therapy may be more practical in certain cases.

OPERATIVE TECHNIC

There are three objects of the operation: (1) the tension in the distended tendon or bursa is relieved, (2) the calcium which acts

as a foreign body is removed and (3) the defective area in the tendon is revascularized. We never excise the bursa; we open its outer layer and we do not suture it at the end of the operation. The tendon heals after removal of calcium without laying down more calcium.

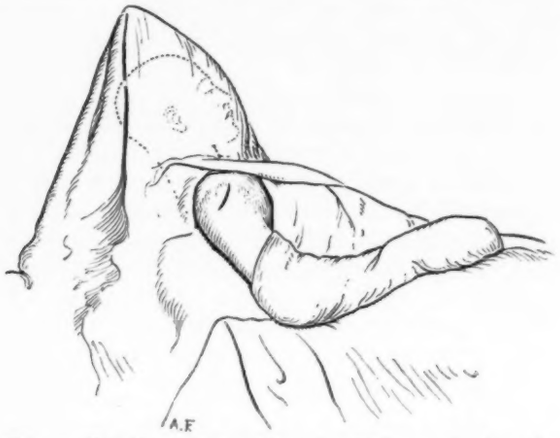

FIG. 7. Draping of shoulder should be such that the extremity may be easily moved in any direction. The patient should be in semi-sitting position, body being flexed to about 45 degrees at the hips. We like the transverse incision although the longitudinal one is equally good.

This would suggest that the calcium was originally laid down in a degenerated tendon and not in a torn tendon. If at operation there are several deposits and any one is left unopened, the patient's symptoms will not be completely relieved. If the incision is carried too low on the shaft of the humerus, bleeding is encountered and a nerve branch may be divided. We prefer a light general anesthetic.

Procedure. The shoulder and upper extremity are so draped that the arm is freely movable in all directions. (Fig. 7.) A 2 inch vertical or transverse incision is made over the shoulder in the deltoid region just below the acromium. The incision is carried through the skin and outer deltoid fascia. The muscle fibers are split and retracted. The deep layer of deltoid fascia is very thin. The subdeltoid bursa is next approached and is immediately incised and contents, if any, are evacuated. The bursa will often show varying degrees of inflammation but as a rule is not very thickened. It is very easy to go through both layers of the bursa especially when they are adherent, in which instance there is some tendency to bleed. As soon as the bursa is opened long narrow retractors like the McBurney retractors are used to spread the deltoid muscle and the outer bursal edges. The flexed elbow is grasped and the shoulder is then rotated exposing the entire cuff. Specifically we carefully inspect the tendinous attachment areas of the subscapularis, the tendon of the long head of the biceps, the supraspinatus, the infraspinatus and the teres

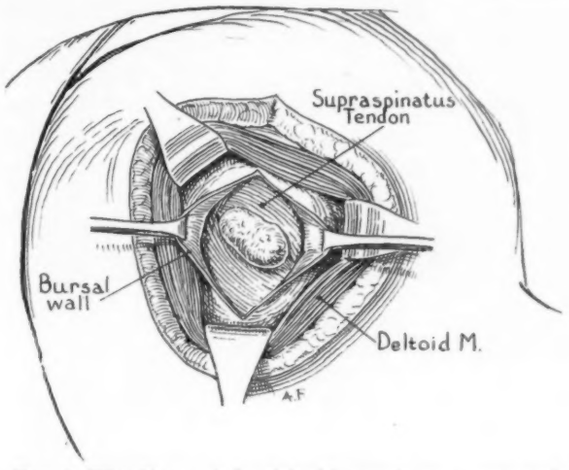

FIG. 8. The fibers of the deltoid muscle are separated; the bursa immediately seen. By rotating the shoulder the tendons are seen blending with the capsule. Deposits appear as elevated, yellowish white areas in the tendon.

minor muscles. (Fig. 8.) The calcium often is placed as a white or yellowish elevation in the tendon just as it passes into the tendinous cuff. The calcific area is then opened in the direction of the fibers of the tendon with a small knife and calcium is scooped out with a tiny curette. Other similar areas are so treated. Care is exercised to be sure that no calcific deposit is left in any one of the tendons. The bursa is not resutured. Quite obviously at this time if any other disorder is detected, it is dealt with appropriately. In closing the wound only the outer layer of the deltoid fascia is sutured, then the subcutaneous fascia and skin.

POSTOPERATIVE TREATMENT

A simple small dressing is applied with elastic adhesive over the wound and the arm is put in a sling. The next day external heat is applied. The patient is requested to use the shoulder and arm. We usually keep them in the hospital two to four days postoperatively. Forty-eight hours after operation we ask the patient to bend over and let his arm swing like a pendulum. The patient usually returns to his work on the fifth or sixth postoperative day with good use of the shoulder but restricted in extreme usage for one to several

more weeks. The aching pain in his shoulder disappears almost immediately after operation.

SUMMARY

In this paper we have attempted to classify patients with calcified tendons and those with secondary subacromial bursitis about the shoulder joint. We have mentioned the main points in surgical anatomy. We have described symptoms, physical findings and x-ray findings on different types of cases. We have suggested what we believe to be the best form of treatment in each type of patient and we have described in some detail the operative treatment.

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DISCUSSION

Boardman M. Bosworth (Bronxville, N. Y.): Some ten years ago I had the opportunity of studying shoulder fluoroscopy on some 12,000 shoulders in the period of three years at annual examinations at the Metropolitan Life Insurance Company. My interest was to discover the incidence of these deposits in the general population, which I found to be 3 per cent, or 3 out of 100. These were deposits that had not given any symptoms at all but were merely picked up on routine examination. I should like to make a plea for fluoroscopic examination of the shoulder for suspected calcium deposits if they are not found on the routine x-ray films. Time and again I have picked up calcium deposits by fluoroscope which were not found in the routine three-plane views by x-ray.

Nicholas J. Giannestras (Cincinnati, Ohio): There is one question I would like to ask Dr. Patterson. I agree entirely, and I am sure all of us do, as far as surgery is concerned, but what about the period of rehabilitation? How long does it take him and what does he do? What panacea, or what magic does he have that these shoulders get well soon after surgery? The ones that I have done have taken a long time. Their period of disability has been a minimum of six weeks, in spite of very carefully regulated daily physiotherapy by well trained personnel.

Russel H. Patterson (closing): To answer the last question first, the patient is usually in the hospital three or four days. He usually returns to his work within seven days, but he does not return to work with full range of motion in the shoulder. Following the operation the acute toothache-like pain is gone, the patient can begin to use the shoulder and within a few days to a few weeks his shoulder will be restored to full use. We have no panacea for shortening this interval. We have not so far had any recurrences following the operative treatment.

We admit that around 80 per cent of all of these deposits will recover and do recover without treatment. What we are trying to show is that in the remaining group there are various treatments that one can use, and we have tried to make suggestions as to what type of treatment will suit what type of case.

We are grateful for Doctor Bosworth's remarks. His study has been very broad. We believe that if the calcium about these shoulders is not absorbed, eventually it will cause symptoms in every case.

USE OF BANK BONE IN THE TREATMENT OF CENTRAL LESIONS OF BONE

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BUSH[2] and Wilson[5] separately reported in 1947 their experiences in two orthopedic hospitals with homogenous bone grafts. They made use of a deep-freeze to store bone obtained at operation or from amputated specimens. They established the fact that refrigerated bone serves as a useful source of bone transplants and that such bone behaves in the host much as does autogenous material.

Additional experimental and clinical experience by Bush and Garber[3] further established the safety and utility of the method and Wilson[6] reported an impressive follow-up study of 214 patients who were subjected to 278 operations in which sterile homologous bone grafts were used. Wilson[6] concludes—

"1. With careful technique homologous bone grafts may be preserved for long periods of time for surgical use.

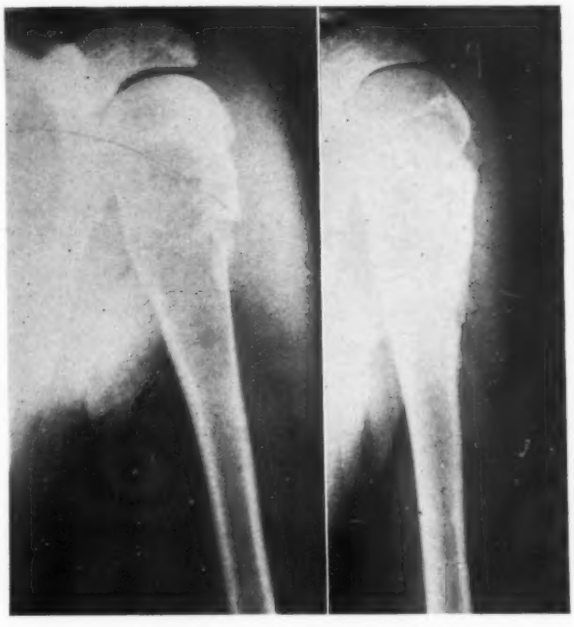
2. Such grafts are well tolerated by human tissues and the risk of infection is no greater than with autogenous grafts.

3. The healing of such grafts takes place by a process of invasion, absorption and replacement similar to that of autogenous bone grafts.

4. The results obtained are identical with those from the use of autogenous grafts except that in some instances the healing appears to be a little slower.

5. The operation of the bone bank is safe and practical. It offers great advantages to the patient and the surgeon from the standpoint of availability, abundance and the elimination of the necessity of secondary operations to obtain bone."

It seems unnecessary to repeat here details which both Bush and Wilson have given concerning the organization and operation of the bone bank. Instead we wish to describe our experiences with this method during a fifteen-month period in which it has been in use on the Bone Tumor Service at Memorial Hospital. During this period we have had a bone bank and have kept an ample supply on hand which has been derived almost entirely from ribs resected on the Thoracic Service by Dr. William L. Watson and his associates. Based on the work of Abbott et al.[1] we would emphasize our belief that ribs constitute an almost ideal source of homogenous bone. Ribs can be converted readily into chips, can be cut with the motor saw into long strips for onlay grafts or can be used in large sections or as matchstick grafts. Being composed of cancellous bone it is believed that they are incorporated in the host more rapidly than cortical strips taken from the tibia. (Fig. 1.)



1A 1B

FIG. 1. A, typical unicameral bone cyst in a six year old boy; B, five weeks after curettage, cauterization and implantation of homologous rib chips.

During the period covered by this report there were sixteen cases (Table 1) in which bank bone was used. Seven were instances of bone cyst (Fig. 2), four were central chondromas (Fig. 3), three were giant cell tumors and one each of fibrous dysplasia and eosinophilic granuloma. (Fig. 4.) Of the bones in-

volved, five were of the humerus, three of the femur, two of the tibia, two were phalanges of the fingers and one each of ilium, sacrum, radius and ulna. The ages of the patients ranged from two to fifty-eight years with an average age of twenty-six; four were under seven years of age. Five of the fifteen patients had been operated upon previously and one of these had undergone five previous operations for the condition for which the operation for use of bank bone was undertaken.

TABLE 1

BANK BONE—SUMMARY OF SIXTEEN CASES

No.	Name	Age	Sex	Bone	Lesion	Date of Operation	Remarks
1.	M. H.	6	M	Humerus	Cyst	12/9/48	
2.	J. W.	6	F	Humerus	Cyst	7/26/48	
3.	V. N.	15	F	Femur	Cyst, rec.	6/7/48	Previous operation 9/19/42
4.	A. A.	13	F	Sacrum	Cyst	3/15/48	Previous operation 12/8/47
5.	R. B.	2½	M	Ulna	Cyst, rec.	4/7/49	Previous operation 10/1/48
6.	S. S.	25	M	Femur	Cyst	5/5/49	
7.	J. E.	8	M	Humerus	Cyst	5/19/49	
8.	B. G.	53	F	Humerus	Chondroma	11/8/48	
9.	S. B.	36	F	Phalanx	Chondroma	2/16/48	
10.	F. B.	41	M	Phalanx	Chondroma	3/21/49	
11.	P. C.	36	M	Humerus	Chondroma	2/28/49	5 previous operations; Lane plate
12.	E. B.	58	F	Tibia	Giant cell tumor	10/4/48	Infection
13.	E. L.	44	F	Radius	Giant cell tumor, rec.	7/19/48	Previous operation 9/23/46
14.	M. H.	37	F	Ilium	Giant cell tumor, mal.	5/24/48	
15.	T. G.	2	M	Tibia	Eosinophilic granuloma	6/23/48	
16.	R. M.	31	M	Femur	Fibrous dysplasia	5/17/48	

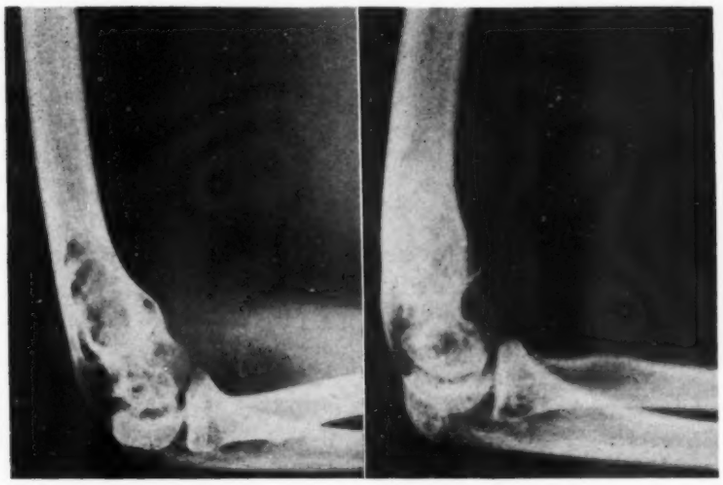
Complications were conspicuously absent save in one patient whose wound infection supervened and later bone fragments had to be removed. The operation was for a giant cell tumor of the tibia and infection was attributed to the fact that one of the operating team had a beginning severe nasopharyngitis. Primary wound healing was achieved in the other fifteen patients or 93.7 per cent.

Ultimate fate of transplated bank bone was satisfactory in five patients who were operated upon long enough ago to permit of evaluation (one year or more). The progress of the others is satisfactory to date.

Elsewhere[4] we discussed the use of massive tibial transplants (autogenous) to repair defects following segmental resection of such bones as the humerus and ulna. Since that report we have added four more cases, two lesions of the radius and two of the humerus, one of which had resection of the upper two-thirds of the humerus including the head and replacement with a corresponding length of the upper portion of the fibula. It might be preferable to continue to use autogenous bone for such large transplants. However, with increasing experience and further indications of the expanding field of usefulness of homologous grafts, subsequent results may justify employment of bank bone even in these cases.

The only question with which we have been considerably concerned is the safety of using bone removed from patients with known cancer. It is realized that a medicolegal problem is posed here and one for which we as yet do not know the whole answer.

Care is taken to use ribs which are apparently free of bone metastasis. Yet the possibility of a minute focus of carcinoma in such ribs cannot be denied. Nor does freezing at subzero temperatures constitute a safeguard since animal tumors are known to survive such exposures. The one factor that we believe constitutes an adequate measure of safety is our confidence in the inability of malignant tumors from one patient to survive and grow in another. So far as we are aware nothing in the past has been published that would support a contention that known cancer can be transmitted by transplantation in humans. However, we do not have much actual accumulated evidence on this point and human experiments along these lines would be extremely difficult



2A 2B

FIG. 2. A, less common location of unicameral bone cyst in a six year old girl; B, six months after curettage and implantation of chips of rib from the bone bank.

FIG. 3. Enchondroma of the middle phlanx of the third finger; the bone bank conveniently provided grafts obviating the necessity of a second operative wound to obtain autogenous bone.

4A 4B

FIG. 4. A, eosinophilic granuloma in a two year old boy; B, result eight months after curettement packing the cavity with chips of rib from the bone bank. Primary wound closure was employed in all our cases.

to conduct on a wide enough scale and follow for a long enough period to offer truly convincing evidence.

For the time being we consider it safe, with proper precautions, to use bank bone taken from ribs of patients who have had exploratory thoracotomies for lung or mediastinal tumors. But if it were practical to obtain bone from *presumably* non-cancerous patients, we would perhaps be running less risk of medicolegal complications and it is also possible that we might be exposing our patients to less risk.

CONCLUSIONS

Bank bone has been used at Memorial Hospital for the past fifteen months for sixteen patients. There was one wound infection. Bone regeneration in the area filled with homologous bone particles has been satisfactory. In some specialized procedures autogenous bone may be preferred but it would seem reasonable to assume that homologous bone would serve equally well. The question is raised as to the advisability of depending upon bone removed from known or suspected cancer patients.

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DISCUSSION

Bradley L. Coley (New York, N. Y.): I shall limit myself more or less to a discussion of the possible hazard of using bone taken from a patient operated upon for at least a questionable tumor of the mediastinum or lung. As Dr. Higinbotham implied, we take great pains to assure that these ribs are not affected. They certainly show no roentgenographic evidence of metastasis but I think one must grant that any patient with cancer anywhere may have a microscopic focus of the disease in any bone in the body even though the chances are extremely slight.

We had hoped that freezing for long periods at sub-zero temperatures would perhaps be a safeguard but we know now that we cannot assume this to be so since we know that animal tumors can survive freezing for long periods and remain viable.

However, as Dr. Higinbotham pointed out, we believe there is a safety factor in the inability of human cancer to grow in one patient after removal from another. We have been unable to find anything in the literature that would indicate that transplantation of cancer from one patient to another has ever been noted. Unfortunately, to prove this on the human would be very difficult and would involve a long follow-up. I have discussed the possibility of human experiments with others and we do not believe it is practical at the present time. Therefore, for the time being we consider it to be safe, with proper precautions, to use bank bone taken from the ribs of patients who have had exploratory thoracotomies for mediastinal or lung tumor. We would prefer to discard those specimens of ribs which have been reported by the pathologist as definitely showing malignant tumor. Unfortunately thoracotomies for benign conditions are not done frequently enough in our hospital to afford us a sufficient supply of bank bone.

Someone suggested, "After removing the bone from the jar in which it was refrigerated, why not drop it in the instrument sterilizer and boil it for a few minutes just before using it?" We have not been anxious to use boiled bone, believing that it would not behave in the host as favorably as refrigerated bone or as fresh bone directly from the patient or the donor.

John C. A. Gerster (New York, N. Y.): I might suggest to Dr. Coley and Dr. Higinbotham that as there is a vast amount of thoracoplasty for tuberculosis being done and all those bones are being thrown away by the operators, these bones might be contributed to their bone bank. Just the way the corneal transplants are gathered from various places, so, in the case of bone, this might be done. I am sure the thoracic surgery service at the Lenox Hill Hospital would be glad to furnish a generous supply of such bone. The speakers would not have to worry about potential cancer if they did not mind using uninfected bones from tuberculous chests.

Norman L. Higinbotham (closing): I would like to thank Dr. Gerster for his very kind offer of tuberculous bones but I think Dr. Coley and I would both prefer to use bones from cancer patients. I believe cancer would be less transplantable than tuberculosis would. We are reasonably sure, although we can not prove it, that cancer cannot be transplanted from one human to another. I think tuberculosis could, very readily, and if these patients are operated upon for tuberculosis, I think they would be more apt to carry the hazard of transplantation than cancerous bone.

THE MANAGEMENT OF CHRONIC SUPPURATIVE OSTEOMYELITIS OF THE FEMUR*

G. Edmund Haggart, M.D. and Melvin T. Hurley, M.D.
Boston, Massachusetts

SINCE the antibiotics have become available, notably penicillin, the treatment of chronic suppurative osteomyelitis has been changed from that of the technics previously employed. However, in patients with infections of long duration, particularly in those individuals who present involvement of the femur, we believe that it is essential to combine surgery with drug therapy in order to achieve a satisfactory result.

It is the purpose of this paper to present our experience and the results obtained in the treatment of long-standing chronic osteomyelitis of the femur in twenty-one consecutive patients. This is admittedly a small series; nevertheless, these patients illustrate the severe systemic reaction consequent upon such an infection together with the details of management which with one exception have saved the extremity and led to complete healing.

PROCEDURE

A detailed and thorough history is taken and a physical examination carried out including complete blood counts, urinalysis and sedimentation rates as well as blood grouping. In those individuals with a draining sinus present bacteriologic investigation is done including sensitivity tests on the dominant organism with penicillin and streptomycin.

The next and a most important step in this preliminary study is an injection of diodrast into the sinus tract performed in the Department of Radiology where stereoscopic anteroposterior and lateral views of the involved area are obtained. (Fig. 1*a* to *d*.) Since one of the major objectives at surgery is excision of the sinus tract, it is most important in planning the operation that as accurate an idea as possible is obtained of the extent of the tract as well as illustrating the particular area of bone involved. So strongly do we believe on this score that three patients (not included in this series) admitted during the past year with a sinus tract recently healed were repeatedly observed until the sinus again opened and this injection could be carried out.

Before surgery the patient is given whole blood transfusions to restore a more normal blood picture as without exception all patients in this series exhibited a degree of anemia sometimes quite pronounced. Furthermore, administration of the selected antibiotics as determined by the sensitivity test is begun forty-eight hours in advance of surgery and continued thereafter as seems indicated. In this series the hemolytic staphylococcus aureus was isolated in 34 per cent and the non-hemolytic staphylococcus in 46 per cent of the patients, hence penicillin was the agent of choice. The dosage averaged 3,000,000 units every twenty-four hours. Later, for the comfort of the patient and with satisfactory progress, it was shifted to 600,000 units of crystacillin given in two equal doses over the same interval.

OPERATION

Following appropriate preparation the first step is to inject the sinus tract with methylene blue under considerable pressure. In the presence of multiple sinuses every effort is made to block their exits temporarily so that the entire tract can be thoroughly impregnated with the dye. This procedure has been of great assistance in accurately delineating the walls of the tract so that all of it may be excised.

A direct lateral approach to the femur, splitting the fibers of the vastus lateralis just above the lateral intermuscular septum, has been found most satisfactory. In those instances when the bone infection was confined to the distal portion of the femoral shaft, the vastus lateralis was displaced anteriorly. There is initially considerable bleeding but this can be quickly checked by careful hemostasis; its effects are also combated by transfusions given during the procedure. We do not favor the anterolateral approach in these patients because of later limitation of knee joint motion due to adhesions of the quadriceps musculature

* From Department of Orthopedic Surgery, The Lahey Clinic, Boston, Mass.

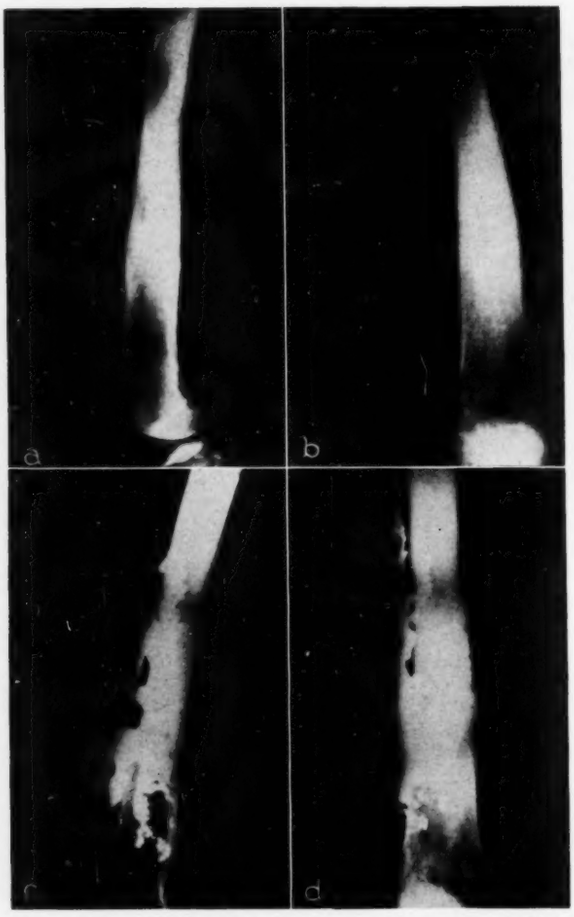

FIG. 1. Case E. G. Chronic suppurative osteomyelitis of eleven years' duration; *a* and *b*, admission roentgenograms; the oval defect in the bone is the result of previous surgery elsewhere; *c* and *d*, extent of sinus tract is shown following injection with diodrast.

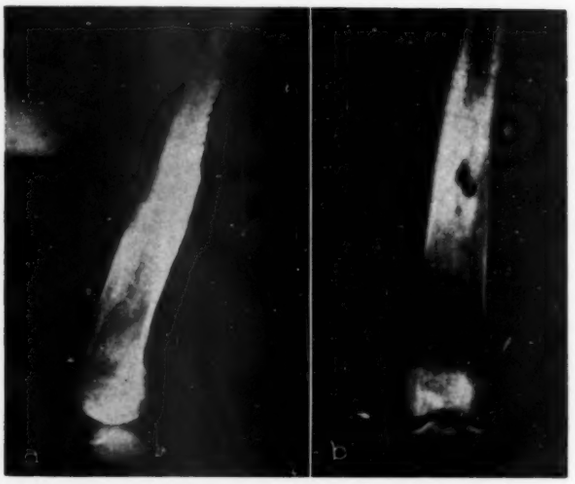

FIG. 2. Case E. G., *a* and *b*, postoperative roentgenograms illustrating the amount of infected bone removed; the previous operative defect shown in the anteroposterior view was not disturbed as it was simply a window in the bone with no immediately adjacent active infection.

FIG. 3. Case E. G., *a* and *b*, four years five months after surgery; patient asymptomatic; note regeneration of bone.

to the shaft of the femur. Posterior exposure of the bone is not acceptable because of possible involvement of the sciatic nerve in the infection and scar as pointed out by Bosworth.[1] A tourniquet is not employed.

The only instances in which we have utilized a more anterior incision were in those patients with osteomyelitis of the proximal third of the femur when the dissection was carried down between the sartorius and tensor fascia femoris muscles.

Following removal of the sinus tract the femur is carefully inspected and the findings checked with those on the x-ray film. Series of drill holes are made in the cortex to outline the area of involved bone which is then removed by connecting the drill holes with an oblique osteotome and a motor saw. It is not only necessary to remove all of the obviously infected bone and sequestra both within and outside of the marrow cavity but also sufficient bone is cut away to make certain that no "pooling" may form after the wound is closed. (Fig. 2*a* and *b*.) In other words it is essential to excise part of the lateral and posterior cortex in the area and in some instances may be necessary to take out a portion of the medial cortex.

After thorough cleansing of the wound with saline irrigations anteroposterior and lateral portable x-rays are taken to determine whether an adequate excision of infected bone has been performed and also to make certain that there are no bone fragments left in the wound. The latter is particularly prone to occur because the bone in question is so sclerotic that it splinters and small fragments of bone may be overlooked

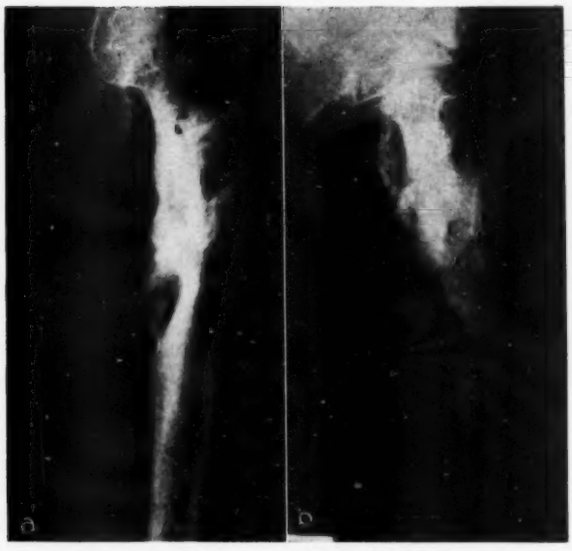

FIG. 4. Case R. T. D., *a* and *b*, admission roentgenograms with diodrast injection; osteomyelitis of five years' duration subsequent to a series of boils; multiple sinus tracts present.

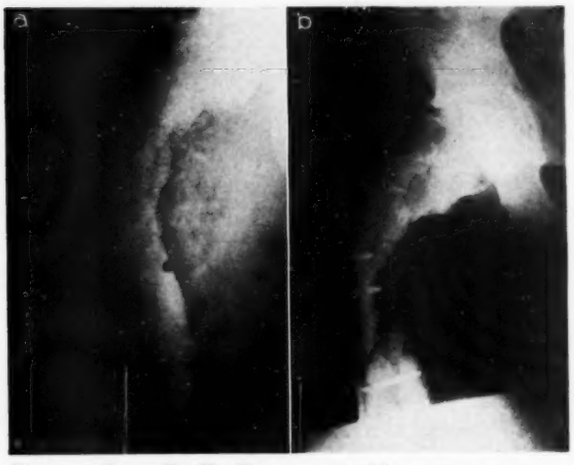

FIG. 5. Case R. T. D., *a*, portable roentgenogram taken in operating room illustrating the large amount of bone that had to be removed so that the patient sustained a fracture which was thereupon plated; *b*, short proximal screws penetrate all that remained of the cortex. In the preparation of the x-rays the films were inadevertently reversed.)

in the soft tissues unless check-up x-rays are taken.

Following the final review of the entire field for bleeding points the wound is firmly closed in layers without drains. If a large operative defect in the femur has been created, the patient is initially placed in a single plaster hip spica, otherwise in suspension and adhesive traction applied to the skin of the lower leg.

Muscle transplants to fill in the bone defect as suggested by Starr[2] and Prigge,[3] have not been utilized in this series because our experience with this procedure in patients treated prior to this group was not particularly successful. No attempt has been made to pack the defect in the femoral shaft with bone chips. This may be an additional technic of value but in the first patients of this series it would have been necessary to obtain bone from another site in the same patient. In consideration of the magnitude of the combined procedures this was considered ill-advised. Now with the aid of the bone bank such an additional step is more feasible. On the other hand our experience with the rate at which adults regenerate bone (Fig. 3*a* and *b*) has been such that at present we are not utilizing the bone bank facilities for these patients.

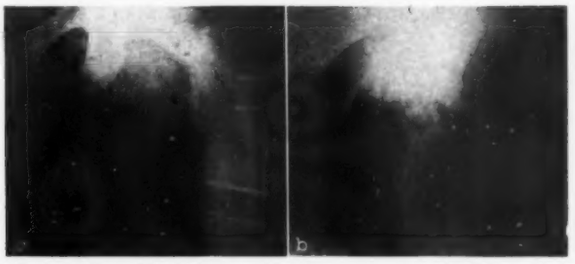

FIG. 6. Case R. T. D., *a* and *b*, seven months following surgery the patient refractured the femur in an automobile accident; note the previous fracture healed and the extensive regeneration of bone. The fracture line is not visible in lateral projection.

COMPLICATIONS

As shown in Figures 4 and 5*a* and *b*, the shaft of the femur is weakened by wide removal of bone over an extensively involved area. This particular patient suffered a fracture of the proximal shaft at the time of surgery which was thereupon plated (Fig. 5*a* and *b*) and the wound healed by first intention. Seven months later he was asymptomatic but in an automobile accident he refractured the femur in an area just above the previous fracture which was healed; the fragments fortunately were held by the upper end of the plate. (Fig. 6*a* and *b*.) From this the patient also recovered without incident and despite the additional trauma he has not at any time exhibited signs of recurrent osteomyelitis during the twenty-eight-month period of follow-up. (Fig. 7*a* and *b*.)

One other patient who healed by first intention sustained a fracture through the saucerized area of the distal femoral shaft twenty-two months after surgery as the result of a severe

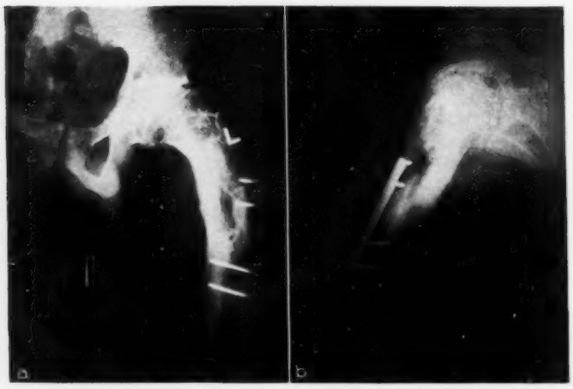

FIG. 7. Case R. T. D., *a* and *b*, three years four months following the operation; patient asymptomatic with normal range of hip and knee motion.

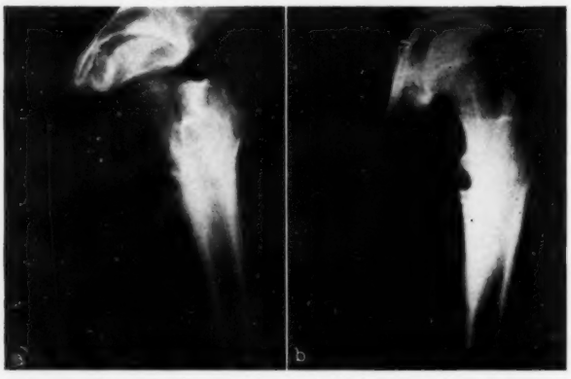

FIG. 8. Case R. S., *a*, first admission roentgenogram; note area of bone destruction about the region of the lesser trochanter; *b*, postoperative film; note bone removed in region of lesser trochanter.

FIG. 9. Case R. S. Film on second admission; large abscess cavity of proximal femoral shaft is evident.

fall. The x-rays then and since that time, thirty-nine months since his operation, have shown no further evidence of active osteomyelitis.

There have been no incidents of postoperative embolism or thrombosis. When the area of bone removal was adjacent to the region of the femoral condyles, there was a temporary loss of knee function but in every instance the preoperative range of motion was regained.

ANALYSIS OF END RESULTS

In this series of twenty-one consecutive cases of chronic suppurative osteomyelitis of the femur there were twelve males and nine females, with an average age of twenty-seven years for males and thirty-five years for females. Fifty-four per cent of the cases involved the right femur and the left femur was infected in 47 per cent. The average duration of symptoms in all cases was nine and a half years ranging from a maximum of twenty-eight years to a minimum of one year. Sixteen patients, 76 per cent, presented draining sinuses in the region of the involved bone. The disease was of hematogenous origin in all instances except in three patients. In one infection followed a gunshot wound; in the remaining two infection was the result of open reduction and internal fixation of fractures performed elsewhere.

Of the total series sixteen or 76 per cent healed by primary intention and have remained healed and symptom-free for an average period of 2.7 years. The longest follow-up on any one of these patients healing by first intention was nine years, the shortest eleven months.

The results in four patients as compared to those previously noted have been classified as good. All healed by first intention following surgery but developed subcutaneous abscesses in the scar from three to nine months after operation. In each instance these were localized processes. The x-ray revealed no evidence of active bone infection nor at the time the abscess was incised and drained, which was the treatment plus a ten-day course of penicillin, was

FIG. 10. Case R. S., *a* and *b*, roentgenograms following the second and definitive procedure.

there any evidence that the abscess communicated with the femur. Since incision and drainage in these four patients they have remained healed and have been asymptomatic for a period ranging from one year in the most recent case to six years in the longest follow-up.

In a fifth patient, a failure, delayed healing occurred but in one year's time the process again became very active; the sinuses reappeared and this patient eventually came to thigh amputation. Two years following this procedure he was asymptomatic and ambulatory with a well fitted prosthesis. It is our belief that in this instance the failure was the result of a combination of factors, viz., the patient was a sedentary, overweight male of forty-nine who gave a twenty-eight-year history of suppurative osteomyelitis of the left femur with multiple draining sinuses and repeated operations. When he was admitted to the hospital October 23, 1945, the anterolateral soft tissues of the thigh presented an almost board-like rigidity due to extensive scar formation. Among the organisms cultured was a persistent Freidlander's bacillus which became resistant to streptomycin. When the patient was first operated upon on November 13, 1945, this particular organism was found only at the time of surgery. Previous cultures of the sinuses had not revealed it. Streptomycin was then available in comparatively minimal amounts. We were fortunate in being able to obtain 1,000,000 units which in combination with penicillin and surgery led to complete closure of the sinus tract. The patient's general condition was then noted as satisfactory only to have a recurrence a year later.

CASE REPORT

The following case report illustrates the steps in the development of our present plan for the management of chronic suppurative osteomyelitis of the femur. This patient was under treatment both before and after penicillin became available. In the first procedure the patient was given intensive sulfathiazole therapy while the surgery was not as radical as is now believed indicated.

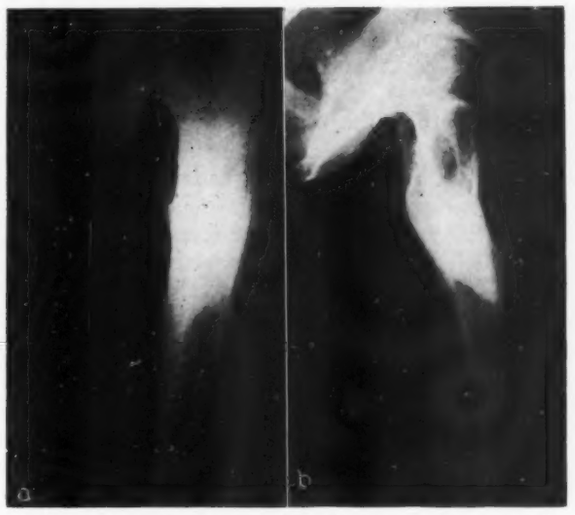

FIG. 11. Case R. S., *a* and *b*, four years ten months following the second operation; patient as ymptomatic with normal hip and knee motion; note regeneration of bone.

R. S., a male student of eighteen, was first seen November 23, 1942, because of an acute suppurative osteomyelitis of the femur with large abscess formation in the proximal thigh and with an area of bone destruction about the lesser trochanter together with sclerosing osteitis of the proximal shaft of the femur. The patient stated the first symptoms occurred in September, 1941, following a severe blow on the upper left thigh while playing football. There was no soft part abrasion or wound. He was at that time given sulfonamide drugs, put in a cast for an interval and was thereafter completely asymptomatic for one year when a small abscess developed in the upper thigh and drained for a few days. After this he again felt well until one week before admission when another abscess appeared. For this he came under our supervision. (Fig. 8*a*.)

Following intensive sulfathiazole administration operation was performed November 27, 1942, when a very large subcutaneous abscess in the anterolateral left thigh was drained. From it a tract led to an area of bone destruction involving the lesser trochanter in which there was a cavity which contained a teaspoonful of pus. The walls of the abscess cavity, sinus tract and area of involved bone were excised and the wound healed by first intention. Figure 8*b* is a roentgenogram taken January 21, 1943, when the patient was ambulatory on crutches and progressively increasing activity.

This man thereafter remained well until August

20, 1943, when a small sinus developed in the lateral proximal left thigh from which he reported some slight initial discharge. However, when seen on the date noted there was none nor was there any evidence at that time of active bone infection. The sinus promptly closed and the patient then was asymptomatic until he was readmitted June 30, 1944, because a sinus had formed. At this time the x-rays (Fig. 9) revealed an abscess cavity in the proximal femoral shaft. Diodrast injection of the sinus showed the tract leading to the abscess and a shorter branch posterior to the femur. The report on cultures was again hemolytic Staphylococcus aureus and very sensitive to penicillin. Therefore, the patient was placed on intensive penicillin therapy.

At operation, July 17, 1944, the large bone abscess cavity was cleaned out and the adjacent infected bone widely excised. (Fig. 10*a* and *b*.) The wound healed by first intention and has remained healed and the patient asymptomatic up to his last visit May 6, 1949, four years and ten months after operation. At this time the x-rays (Fig. 11*a* and *b*) still exhibit persistent sclerosis of the femur but no evidence of active bone infection.

SUMMARY AND CONCLUSIONS

With a combination of antibiotic therapy and adequate surgery the treatment of chronic suppurative osteomyelitis of the femur now offers a more hopeful prognosis.

Accurate delineation followed by complete excision of the sinus tracts and thereafter thorough removal of infected bone are the significant procedures at operation.

The details of and end results obtained in the management of twenty-one consecutive patients with chronic suppurative osteomyelitis of the femur are presented.

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DISCUSSION

Stephen S. Hudack (New York, N. Y.): I would like to congratulate Dr. Haggart on his courageous attempt at tackling an extremely complex and difficult problem. Dr. McLaughlin tells me that he has operated on a patient who had a cured osteomyelitis approximately at the age of five and operated at the age of fifty-four for osteomyelitis, with a quiescent period in between. I, myself, have seen one with approximately a forty-two-year span.

Three months ago I operated on a boy who had been operated on by the elder Albee and more recently by someone else for a cup arthroplasty, with fused hips having had a fifteen-year history of bilateral chronic osteomyelitis. The dominant factor there was a hemolytic staphylococcus aureus. When the cup was removed, there was a large posterior shelf of bone from which two pockets culturing bacteria were excised. This had existed for a period of fifteen years, as I said, having been operated successfully twice with primary closure of the operative wounds.

I would really like to know in some of this diseased bone what lets Dr. Haggart decide where he stops cutting the diseased bone? At the present sitting I have no way of knowing where the diseased bone or the bacterial invasion of the haversian canals, for instance, actually ceases. I wish he would tell us or give us a guiding sign.

G. Edmund Haggart (closing): In the first place I would emphasize that, obviously, I do not know if these people will all continue well. You saw those end results. The patients still have bone sclerosis. All I know is that they have gone this far and it is a fairly good follow-up to date. We aim to keep after them. We hope they will continue asymptomatic; they have done better on this therapy than any other type we have encountered.

As to where you stop cutting, etc., one of the things that has helped us the most has been the delineation of the sinus tract. When present it has led to the bone and that has been, so to speak, the locus from which we began and around which we planned the extent of the excision. With the lateral and some of the posterior cortex then removed, you clean out the medullary portion of the bone trying always to save at least the anterior aspect. Sometimes you cannot. It has been our experience that with the area of bone infection well exposed, you can follow a more or less definite abscess cavity. You cannot see this in the x-ray but it really exists up to a point where it is blocked off in the shaft. Twice in my experience with this group we have come into what appeared to be normal marrow and I was considerably disturbed because I thought, "Well, that means the infection goes right on up the shaft." Fortunately, it did not nor has there been any evidence so far of doing so. In those two cases one has been followed five and the other four years and some months.

I think the answer to Dr. Hudack's question is in summary that the abscess cavity within the bone, having excised the walls and removed the sequestra, etc., has been the factor which has delineated the extent of surgery and stopped us from excising any more bone. You will note, finally, in that one illustration, as I told you, there was an opening like a window (and that is exactly what it was in the bone) from previous surgery. There was no evidence of infected bone around it that I could see and, therefore, we left it alone and did not go into that area.

MAJOR AMPUTATIONS OF THE EXTREMITIES DUE TO TRAUMA

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Chicago, Illinois

THIS article is an analysis of seventy-six major amputations performed on sixty-seven individuals. These cases were assembled through the years 1937 to 1948 inclusive and include both civilian and industrial traumas. Only those cases in which all of the phalanges were amputated are included. (Table 1.)

TABLE 1

AMPUTATIONS (SIXTY-SEVEN CASES)

	Number		Per cent		Deaths (Eight Cases)			
					Single		Double	
	Single	Double	Single	Double	No.	Per cent	No.	Per cent
Arm	10	..	14.92	.....	2	2.99		
Forearm	5	..	7.46					
Wrist and hand	3	..	4.49					
Thigh	12	5	17.91	7.46	2	2.99	2	2.99
Leg	23	4	34.34	5.96	1	1.49	1	1.49
Ankle and foot	5	..	7.46					
	58	9	86.58	13.42	5	7.47	3	4.48
	67		100.00%			11.95%		

PREOPERATIVE PROCEDURE

First Aid Treatment. First aid was available in many instances by people who had been instructed in first aid. The injured were allowed to lie within a few feet of where they were hurt. Tourniquets, stretchers and blankets were available. Doctor and ambulance were at the scene of the injury within eight to ten minutes. Morphine sulphate was administered for pain. After the doctor arrived the injured person was prepared for transportation where the tourniquets were re-examined and blood plasma was started if indicated. The patient was then transferred to a standard hospital a few minutes or a few miles away.

Evaluation for Surgery. The patient's history, age, general physical condition and all important factors are taken into account. In a case in which the extremities were so badly crushed that there was no hope of survival, preparations were made in surgery to remove the extremity as soon as the patient had responded from shock and loss of blood. Blood plasma, whole blood and antibiotics were readily available. Large quantities of blood plasma and whole blood may be administered in a relatively short period of time. In most instances when other serious complicating injuries did not exist, the patient was in a satisfactory condition for guillotine or definitive surgery in from two to three hours.

Preparation and Time of Amputation. Erythrocyte and leukocyte blood counts and hemoglobin estimation were carried out as well as urinalysis. Portable x-ray machines showed the level and comminution of the bone fragments. The circulation of the extremity distal to the point of injury was estimated. When any indication exists that there is a possibility of

saving any part of the injured extremity, surgery is postponed until there is no question of doubt that the amputation is necessary. The injured extremity may be suspended in a well padded splint and, in some instances, extension is advisable. It is surprising how many badly crushed extremities will respond to gentle care.

Anesthesia. Working in several hospitals makes a variety of anesthetics necessary. In one instance a nurse anesthetist is very adept at inhalation anesthesia. In another hospital intravenous pentothal and inhalation oxygen is the anesthetic of choice. At a third hospital low spinal anesthesia reinforced with a minimum of pentothal sodium intravenously is the anesthetic preferred. There is no question of doubt that the graduate doctor who has specialized in anesthesia has available many methods of anesthesia to the best interests of the critically injured patient requiring amputation.

Determination of Amputation Level. Guillotine amputation when necessary is carried out at the lowest level of bone viability. This is sometimes ambiguous when extensive avulsion of the skin has occurred. There is a limit to which viable skin can be stretched from adjacent parts.

EXTREMITIES INVOLVED

Foot. Basic facts about thousands of amputations in war and peace are available in the literature. A difference of opinion does exist. The British, for instance, want no part of a Chopart amputation while the Canadians report excellent results in quite a series of cases. The Americans believe that Chopart's amputation has merit and will explore it further. While amputation through the foot has been looked upon with disfavor by most authors, it is interesting to note the divergence of opinions. Kirk[4] in 1944 expressed himself about the equinus deformity and tilting of the os calcis which occurs because of the unopposed pull of the tendo-achilles. McKeever[5] in 1946 stated that the Chopart amputation was doomed to failure and should not be done if the muscles in front of the leg had lost their attachment to the stump of the foot. McKeever[6] in 1947 was of the opinion that if muscle balance was lost in the foot stump, progressive deformity usually resulted which ultimately produced a fixed deformity. A fixed deformity in turn makes weight-bearing painful and may make it impossible to wear a shoe.

In the normal foot the flexion and extension of the foot is perfectly balanced in association with the mutual balanced muscular cooperation of pronation and supination.

In trauma of the foot when amputation is indicated, a long plantar flap is necessary. Kirk believes that the highest permissible level of amputation of the foot is distal to the bases of the metatarsals. This is indeed an ideal situation but much can be done, however, with considerably less. McKeever,[6] furthermore, is pessimistic about amputations proximal to the bases of the metatarsals because in his experience inversion deformity of the foot along with calluses on the outer anterior side of the stump and ultimate equinovarus deformity has resulted. In arteriosclerotic gangrene, diabetic gangrene, thrombosis, embolism, neoplasm and thrombo-angiitis obliterans; other factors play complicating roles. In this series of cases these conditions did not primarily exist.

Crego and McCarroll,[2] Scuderi[7] and other authors present series of cases of poliomyelitis and irreparable nerve injury in which extremities have been stabilized for the correction of deformity. Undoubtedly abnormal muscle pull is the most common underlying factor of the deformity. When flexion-extension and pronation-supination groups of normal muscles are available, it seems that we should be able to stabilize the normal, healthy leg muscles that have temporarily lost their normal relations and attachments. Tendons may be repaired and transplanted. The exact procedure to be used depends on the individual case. The individual power of muscles will change after re-attachment. Corrective re-stabilization of the foot through a full range of motion is not usual in most instances because of the change in leverage. (Fig. 1.)

Leg. When a suitable weight-bearing extremity cannot be produced in the foot, the most successful level of amputation in the leg is at the level where the muscle bellies transform themselves into tendons. The average length of tibia useful for prosthesis varies from 5 to 7 inches. The length of 6 inches is about the junction between the middle and upper third of the leg. The fibula is always cut from 1 to 2 inches shorter than the tibia. When the length of the fibula is less than 4 inches, less complications will follow if the fibula is entirely

FIG. 1. Lateral x-ray showing distal tarsal amputation.

FIG. 2. View of partially amputated foot of x-ray shown in Figure 1; motion normal.

removed. Any length of tibia saved between 7 inches and 2 inches is to the best interest of the patient, with respect to future prosthesis. Even this short stump is most useful in the normal use of the knee even though the prosthesis must be attached above the knee. (Figs. 2, 3 and 4.)

Thigh. A level about 4 inches above the distal weight-bearing surface of the femur is the amputation of choice. This level must be associated with a stump that is conical and subsequently properly shrunk; otherwise the knee mechanism of the prosthesis makes the thigh longer than the opposite normal thigh. From the supracondylar level to the hip joint every part of an inch of femur and adjacent tissues are invaluable for use in prosthesis.

Hand. The most suitable amputation in the upper extremities proximal to the metacarpals is to leave all of the carpals. The lower end of the radius and ulna without the carpals has a rather bulky distal extremity and does not take to prosthesis kindly. The distal radius-ulna level is satisfactory for use in holding objects firmly and in assisting with any processes carried out with the opposite hand.

Forearm. If amputation must be carried out through the forearm, a most satisfactory level is the junction of the middle and lower thirds. Any length which must be sacrified proximal to this level has several disadvantages, the most important of which are: (1) there is less bone to act as a lever in the prosthesis; (2) as the prosthesis approaches the elbow, it impinges on the normal range of elbow motion.

Arm. In amputations above the elbow the most satisfactory, useful stump is obtained when the humerus is sectioned from 2½ inches to 5 inches above the distal surface of the medial and lateral epicondyles. The removal of only the distal 2½ inches of supracondylar area does not give adequate space to attach the elbow mechanism. When the distal 5 inches of humerus has been amputated, the triangular widening of the shaft has been entirely eliminated. All bone sacrificed proximal to 3 inches of supracondylar humerus is uncalled for unless absolutely necessary.

TECHNIC OF AMPUTATION

Mechanical tourniquets are removed and the brachial or femoral artery is compressed by an assistant proximal to the operative field in the axilla or groin. A ten-minute soap and water scrub is carried out in the operative field. The level of bone length is measured and marked on the skin. An incision is made through the skin, subcutaneous tissues and aponeurosis of the muscles perpendicular to the skin surface. The skin, subcutaneous tissues and muscular aponeurosis is allowed to retract back in one piece, a distance equivalent to a quarter of the

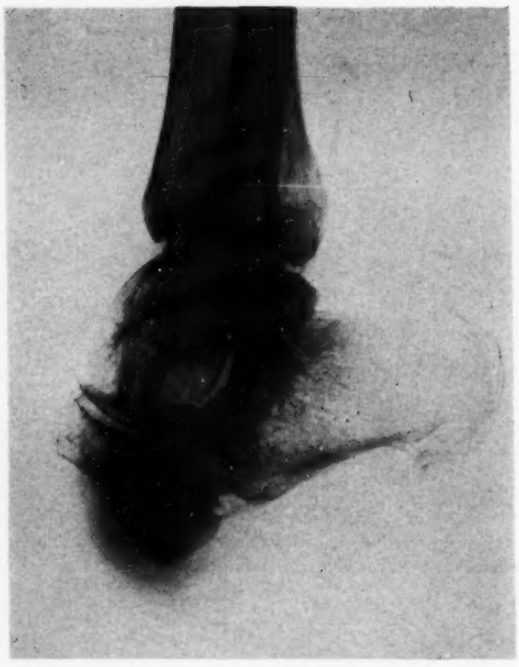

FIG. 3. Lateral x-ray of mid-tarsal amputation.

FIG. 4. Side view of mid-tarsal amputated foot shown in Figure 3.

circumference of the leg at the level of amputation. The muscles are cut circularly around the stump for a third of their thickness and allowed to retract. A second cut is made at the new level through another third of the muscle depth and again allowed to retract. At the final third level the muscles and tissues are cut entirely down to the bone. The periosteum is cleanly cut at bone length with a scalpel, the muscles are retracted and the bone cut off with a saw. The sharp edges of the bone are gently rounded off with a fine file.

The blood vessels are dissected out, clamped, cut and doubly tied 1 inch proximal to the bone end.

The nerve is gently isolated, tissues retracted from it and then cut transversely with a sharp scalpel 2 inches short of the bone length.

A medial and lateral v is removed from the skin, subcutaneous tissues and muscle aponeurosis. A Penrose drain is placed down to the bone, coming out laterally. The muscle aponeurosis alone is joined over the bone end with interrupted sutures of No. 0 chromic catgut. The skin is closed with continuous locked dermal sutures.

Nerves. Phantom limb, painful or painless, and neuromas are complications which sometimes follow amputations. Phantom limb without pain has been noted but other than the eerie sensations and cramped fingers or toes complained of, there was nothing of any serious importance.

Local novocain has been injected into neuromas as a test to determine whether or not the painful symptoms could be obliterated. Novocain has been injected into the sympathetics and ganglions at different levels for the relief of numerous conditions. Gilchrest[3] stresses the value of interruption of the sympathetic nerve supply in post-traumatic osteoporosis. Investigative work is being carried on at the present time on these conditions.

The intravenous use of procaine has been tried in some of these painful and painless conditions and found to be encouraging. One case of causalgia was permanently relieved. Since pain is a subjective symptom, it is difficult to carry out experimental work. Intravenously the procaine works locally, regionally and centrally all at the same time. Previously it has not been possible to wipe out the central impressions of these conditions except with a general anesthetic or a hypnotic for periods of time with little or no chance of permanent relief.

Method for Re-stabilizing the Foot. The most important part of surgery through the foot is that part which has to do with the re-stabilization of the muscle balance. The gastrocnemius, soleus and plantaris are the group of muscles which initiate plantar flexion and are responsible for the equinovarus deformity (if not corrected) after surgery. To do this surgery intelligently it is necessary to know the anatomy and normal physiology of the muscles individually and a basic knowledge of leverage. The number of tendons which have lost their normal insertions depend upon the level at which the foot is amputated. It is thus necessary to hold the foot in balance and re-attach the tendons so that the foot is in equilibrium postoperatively. It may be necessary to use a plaster splint postoperatively for a short time to hold foot in equilibrium.

Crego and McCarroll[2] and others have demonstrated that it is possible to re-stabilize the foot in infantile paralysis. Then, how much easier it should be for us when we have practically normal muscles to deal with. Series of cases in the hands of competent traumatic surgeons show that normal balance and use of the remaining foot can be achieved when dorsal flexor tendons have been divided. The tibialis anterior, extensor hallucis longus, extensor digitorium longus and the peroneus tertius are the natural physiologic antagonists of the gastrocnemius-soleus group. These tendons may be attached to bone or muscle aponeurosis in their line of leverage, or the whole group may be brought out and attached anteriorly. (Fig. 5.)

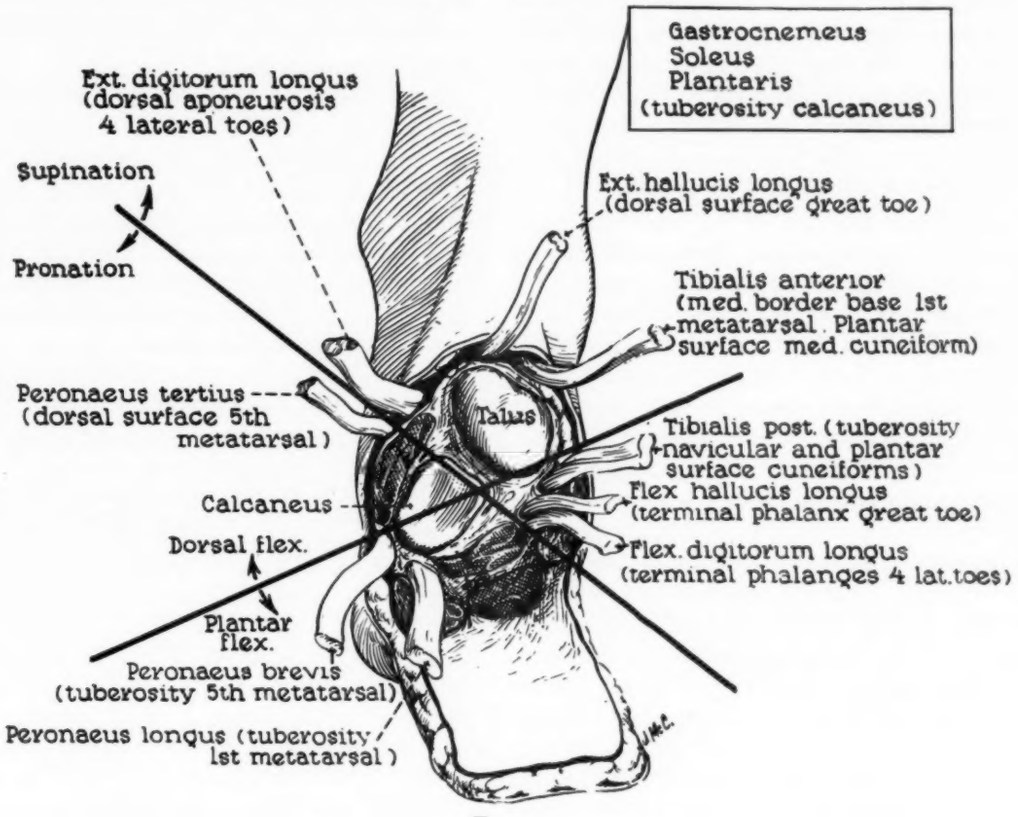

FIG. 5.

POSTOPERATIVE HOSPITAL CARE

A four-way adhesive extension is fixed to the skin of the stump and the straps attached to a square block of wood distal to the stump and dressings. A rope and sufficient weights over the end of the bed are attached to a block to overcome the ordinary retraction of superficial tissues.

The patient is returned to bed and allowed to move around at will, pain permitting. Sufficient sedation is given to control pain. Fluids are given postnausea and antibiotics as indicated. The drain is removed at the end of twenty-four to forty-eight hours depending on the amount of drainage. Passive and active

motion is stimulated at the end of twenty-four hours. When pain has subsided, the patient is allowed to sit up in bed, then in a chair and then up on crutches if it is a lower extremity. Weights are re-attached upon returning to bed. The sutures are removed in about seven to nine days followed by adhesive bridges. At the end of two weeks physiotherapy in the form of heat, massage and whirlpool bath is in order. When the tissues are no longer tender, tight elastic bandages are applied to help shrink the leg promptly.

VOCATIONAL REHABILITATION

A portion of these injured men had available to them a vocational rehabilitation service and took advantage of this service. The injured man's physical and mental ability, age, work-experience and background are taken into account. Thus the plan of training a particular individual is initiated. Some types of training that are available are civil, mechanical, chemical and aeronautical engineering, chemistry, business administration, teaching, journalism, pre-medical, law, music, accounting, laboratory technician, librarian, geology, watch and clock repair, shorthand, comptometry, typing, jewelry making, weaving, re-weaving, sewing, auto mechanics, welding, upholstery, shoe repair, dry cleaning and many others.

An analysis of the weekly income on the old job where the patients were injured and on the new job for which they had been rehabilitated shows that there are very few who are making less than before they were injured. Most of the case histories show that their weekly income is considerably higher.

SUMMARY

1. Seventy-six amputations among sixty-seven individuals have been presented and discussed. There are nine individuals who had double amputations.

2. Methods of amputation are discussed in detail.

3. The intravenous use of procaine has been tried and found useful in some conditions affecting the sympathetic nervous system.

4. A method is suggested whereby all amputations through the foot can be stabilized at the time of surgery thus obviating deformity and painful and useless stumps.

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SUCTION SOCKET PROSTHESIS FOR ABOVE-KNEE AMPUTEES

INTERIM REPORT OF VETERANS ADMINISTRATION EXPERIMENTAL PROGRAM

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A PROSTHETIC device first patented by Dubois Parmelee of New York in 1863 has again attracted the attention of the medical profession. Originally utilized in conjunction with a pylon leg attaching the lower extremity prosthesis to the body by suction, Parmelee's idea had been tried in 1885 by Beacock and Sparham in Canada, in 1911 by Toles in California and in 1926 by Underwood in England. To improve the degree of suction the British added a helical groove in the socket lining. Furthermore they re-designed the appliance for use with a metal leg, the inserted bucket being fabricated of wood or papier-maché. In these earlier limbs the valves varied from a simple faucet to a one-way air escape valve. (Fig. 1.)

Following World War I about thirty suction sockets were fitted at Roehampton, England. Until recently case histories on these thirty patients had been lost and the suction socket prosthesis had been discarded. Then Oesterle of Ulm, Germany, advocated the use of the "Springer Vacuum leg" in 1933.[1] Furthermore, in Germany Felix believed the development of a satisfactory valve for the vacuum chamber was the item that popularized this method of prosthesis fixation in above-knee leg amputations.[2] Next Kirschner and Dittert reported a series of thirty-nine cases in 1944.[3] About the same time Hepp[4] described a contact type of prosthesis, a modification of the suction socket. Some military medical reports on suction sockets received in the United States immediately following V-E Day (May 8, 1945) prompted Major General Norman T. Kirk to appoint and dispatch to Europe in March, 1946, a committee of distinguished civilian and military engineers and orthopedic surgeons to investigate and report upon new orthopedic technics and appliances including the suction socket prosthesis. In 1946 this report was submitted to the National Research Council of the National Academy of Sciences for consideration by The Committee on Artificial Limbs. In 1947 this Committee became known as the Advisory Committee on Artificial Limbs and was selected by the Veterans Administration, Army and Navy to coordinate all research projects pertaining to artificial limbs. It is a pleasure to report that the results of this Committee's activities are real. Many new devices have appeared such as the new arm prostheses designed by Fitch, by Hosmer and by the Northrop Aircraft Corporation. The wrist flexion unit and supinator and pronator device for below-elbow arm amputees represent recent developments.

The department of medicine and surgery of the Veterans Administration has been cooperating with this Committee. At this time among devices for artificial legs in the developmental stage are a new ankle joint incorporating horizontal rotation, several knee brake and lock mechanisms, both hydraulic and mechanical in operation and the suction socket for above-knee amputees. Recently Canty reported his experience at Mare Island Naval Hospital with the suction socket.[5]

Although results obtained on the suction socket prosthesis to this date are most promising it is deemed advisable not to consider them as conclusive. The source material reported here is contained in two reports received in May, 1949, by the Advisory Committee on Artificial Limbs. These reports were rendered by representatives of the limb manufacturing industry and by the Lower Extremity Committee, a technical subcommittee of the Advisory Committee on Artificial Limbs. It is believed that until a significant number of case histories can be compiled on those who have successfully worn the suction socket daily for an entire calendar year under a large variety of climatic conditions, it would be a mistake to claim complete success. Today there are very few surgeons or limb-fitters in this country who could claim to have seen or fitted more than

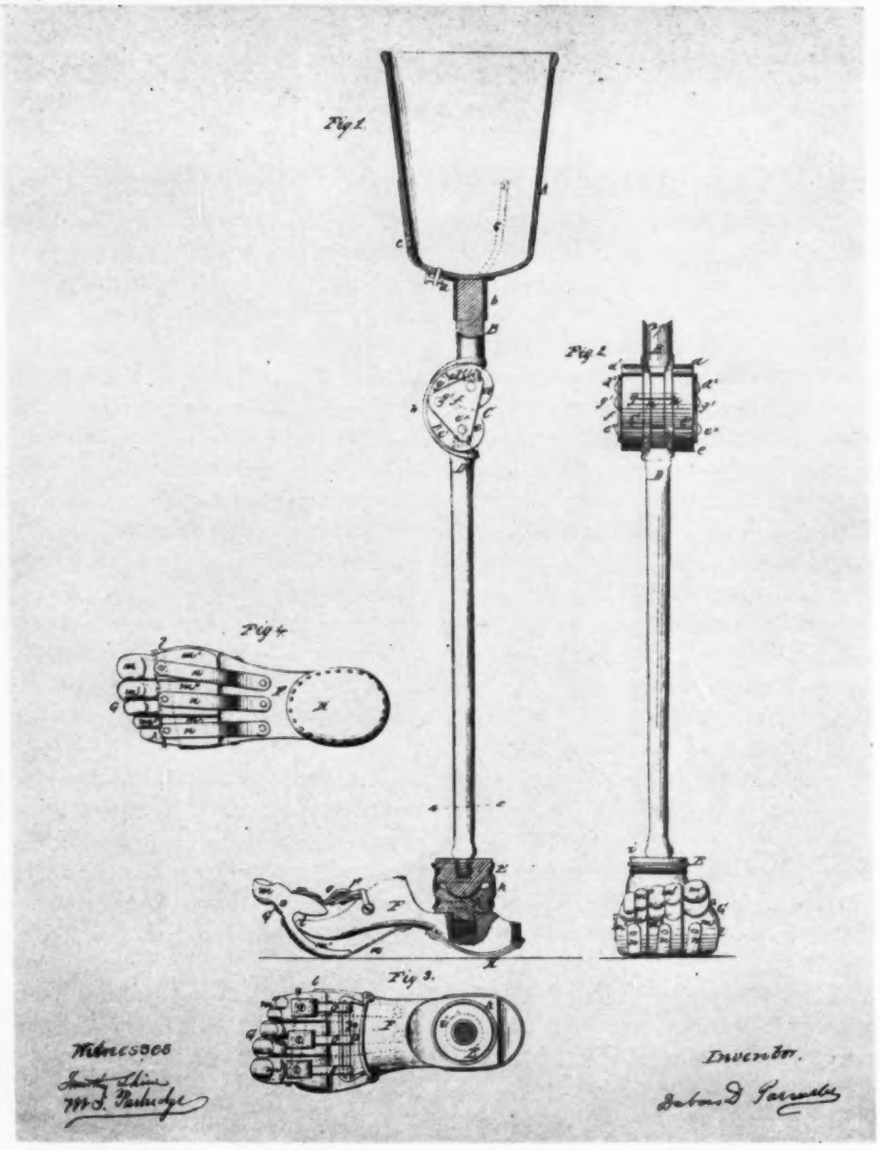

FIG. 1. The first known model of suction socket prosthesis. (U.S. Patent Office, No. 37,637.)

a handful of cases twelve months ago. Therefore, this report is to be considered as merely informational.

The statistics in Table I on above-knee suction socket experience have been compiled from responses to a questionnaire mailed to 159 members of The Orthopedic Appliance and Limb Manufacturers Association.

The Veterans Administration Experimental Suction Socket program which has been in operation less than two years involved first a training program for limb-fitters and surgeons. A total of twenty schools have been held in various parts of the country in which a total of 200 limb-fitters and over 200 surgeons have been certified as qualified to fit the suction socket. Each one of this great number of fitters has been authorized to fit three suction socket limbs to veteran amputees. As of this date 495 suction socket limbs have been authorized to be fitted to above-knee veteran amputees. The most recent report (April 15, 1949) received from Professor Howard D. Eberhart, Chairman of the Lower Extremity Committee of the Advisory Committee on Artificial Limbs, records a total of 211 cases of which nine or 4.3 per cent are considered to be failures. (Table II.) The geographic distribution of these

veterans is widespread involving all degrees of climatic variation.

The causes of the nine failures in the 211 cases reported are tabulated in Table III.

A group of twenty-nine patients exists still alternating in the use of the suction socket and the original conventional limb for reasons listed in Table IV.

It is only reasonable to adjudicate these results by the length of time that the suction socket has been worn. It must be emphasized that in this group of patients in the experimental program 123 or 58 per cent have been wearing the suction socket four months or less and that in this group lie 75 per cent alternating between the use of the suction socket and conventional limb.

Table V illustrates the time interval in those cases in which a suction socket type of prosthesis was used. Inasmuch as only three patients in this series have been wearing the prosthesis successfully for ten months, one may readily comprehend the fact that unqualified approval of this device must be deferred.

To judge these results in the Veterans Administration Experimental Program as good is reasonable. Recalling that most fitters have been authorized to fit only three veterans and realizing that experience in pulling a suction socket is limited in most areas of the country, one might conclude that this report represents a fair measure of success. Moreover it is of importance to point out that successful fitting depends upon a change in the pattern and shape of the socket from the earlier design. Furthermore for the first six months the wearer must report at regular intervals for adjustments. Inasmuch as the stump becomes an active and functioning part of the amputee, stump changes occur. The usual adipose and flabby stump loses its fat tissue and develops more normal musculature. During this period of change the surgeon, amputee and limb-fitter must be particularly conscious of the necessity for adequate follow-up.

At first these sockets were usually fitted too tightly. The degree of suction required is only 1½ pounds per square inch negative pressure which during the stance phase of walking will change to 1½ pounds per square inch positive.

TABLE I*

Number of sockets fitted to above-knee amputees	1,232
Men	1,023
Women	164
Children	45
Number of complete failures	50 (4 per cent)

* From Report of Preliminary Results, OALMA, May 4, 1949.

TABLE II*

BRANCH VETERANS ADMINISTRATION OFFICE DISTRIBUTION OF RESULTS

Branch No.	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
Wearing routinely	0	7	13	7	10	14	8	9	14	4	18	60	9	173
Alternating	0	0	1	4	5	1	0	4	4	0	0	10	0	29
Failures	0	1	1	0	2	1	2	0	2	0	0	0	0	9
Total	0	8	15	11	17	16	10	13	20	4	18	70	9	211

* Report of Subcommittee, ACAL, April 15, 1949.

TABLE III*

REASONS FOR FAILURES (NINE CASES)

Non-cooperation, gave up during initial fitting	3
Poor fit and alignment	2
Medical contraindications:	
Cyst or abscess on adductor roll remaining from using old leg	2
Insecurity (television actor gave up after five months' trial)	1
Loss of suction (mechanic lost suction when lifting motor from chassis)	1
Total	9

* Report of Subcommittee, ACAL, April 15, 1949.

TABLE IV*

REASONS FOR ALTERNATING WEAR (TWENTY-NINE CASES)

New cases, increasing time on suction socket gradually	9
Insecurity on leg, loss of suction, bad alignment	7
No time for proper adjustment, long working hours	6
Replaced old socket, not yet adjusted to new one	3
Wears, except at work	2
Excessive edema and perspiration	1
Insecurity on leg, bilateral amputee	1
Total	29

* Report of Subcommittee, ACAL, April 15, 1949.

TABLE V*

LENGTH OF TIME ON SUCTION SOCKET

Months	0	1	2	3	4	5	6	7	8	9	10	Total
Wearing routinely	0	15	23	31	25	15	16	20	21	4	3	173
Alternating†	0	4	8	5	5	1	5	1	...	...	...	29
Failures†	3	2	..	1	1	1	...	1	...	...	...	9
Sub-total	3	21	31	37	31	17	21	22	21	4	3	211
Cumulative total	3	24	55	92	123	140	161	183	204	208	211	211

* Report of Subcommittee, ACAL, April 15, 1949.

† Months since initial fitting date rather than time on suction socket.

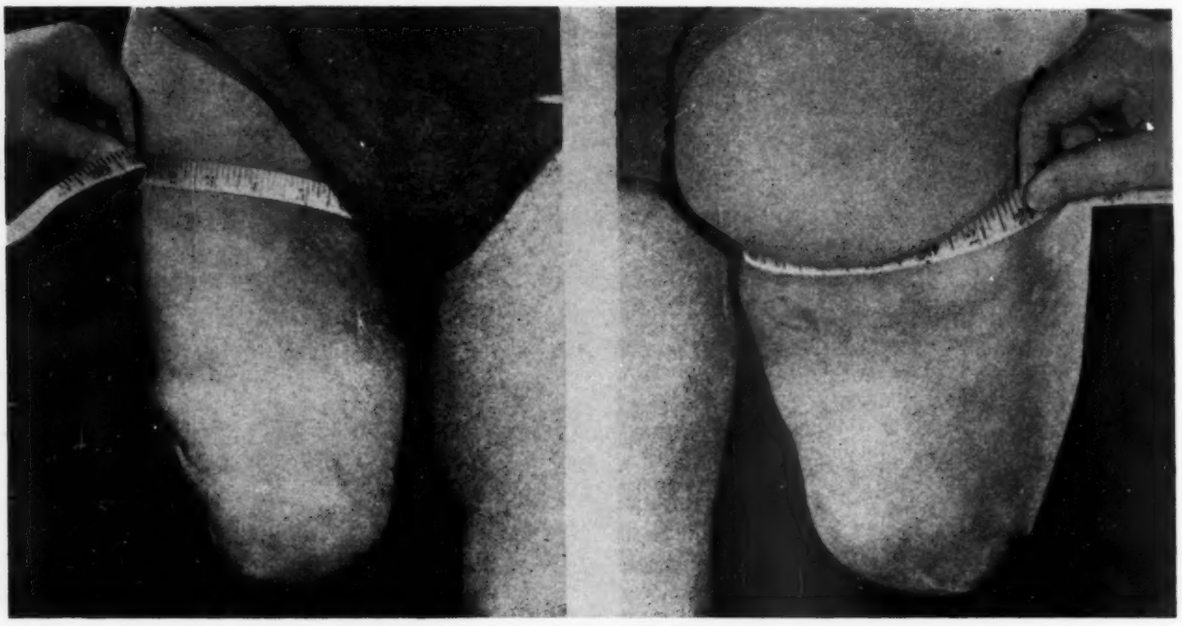

FIG. 2. Perimeter measurement for determining pattern size.[6]

An adequate air-escape valve has been designed so that these pressures are maintained consistently. It is perhaps erroneously termed a suction socket; the degree of suction is minimal. Suction alone holds the artificial limb when the stump is relaxed while during actual walking the holding force is better described as even contact of the stump with the socket wall. The patient by contracting his remaining muscles in the stump can prevent its forceful withdrawal.

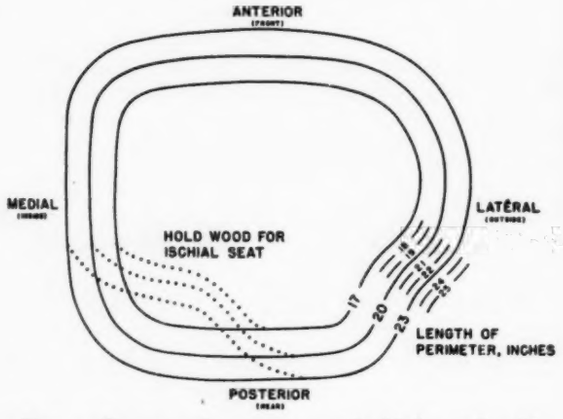

FIG. 3. Cross-section pattern at ischial seat level.[6]

The modification in the shape of the suction socket pattern from the original design can be explained as the result of experience gained. It would be well to list the main changes as follows: (1) reduction in size of the ischial seat; in about 5 per cent of the cases fitted the ischial seat may be eliminated (indicated if a large and powerful gluteal muscle bundle is present); (2) properly shaped posterior surface of the

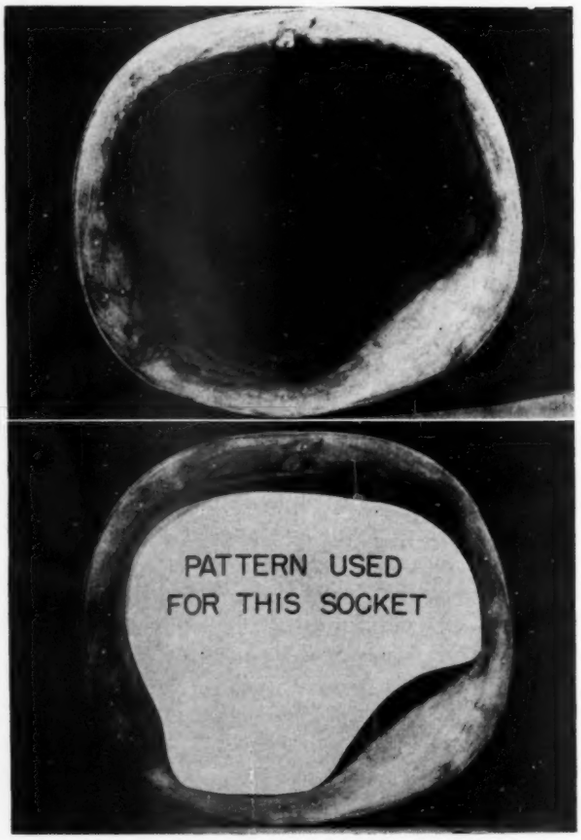

FIG. 4. Deviation from pattern of a typical suction socket.[6]

thigh making the back of the socket thinner and flatter, sometimes utilizing a soft back; (3) "easing" the fit on the walls of the socket all around below the level of the brim; (4) greater emphasis in proper alignment of the entire limb.

The main advantages in this suction socket type prosthesis are: (1) providing the above-knee amputee with a naturally functioning hip joint whereby his remaining muscles in the stump and about the hip resume physiologic balance resulting in better coordination; and (2) abolishing the suspension straps or pelvic belt with hinge. Suspension by a pelvic belt and a metal hinge in the conventional leg prevents necessary rotation in proper walking and has resulted in a high degree of belt breakage. On the other hand the amputees claim that suction socket type prosthesis feels as if it were a constituent part of the stump, resulting in improved control and position sense. In addition the wearing of a stump sock is no longer necessary.

There is not space to describe the details of fabrication of this type of socket. Suffice it to state that a willow block is carved to form-fit

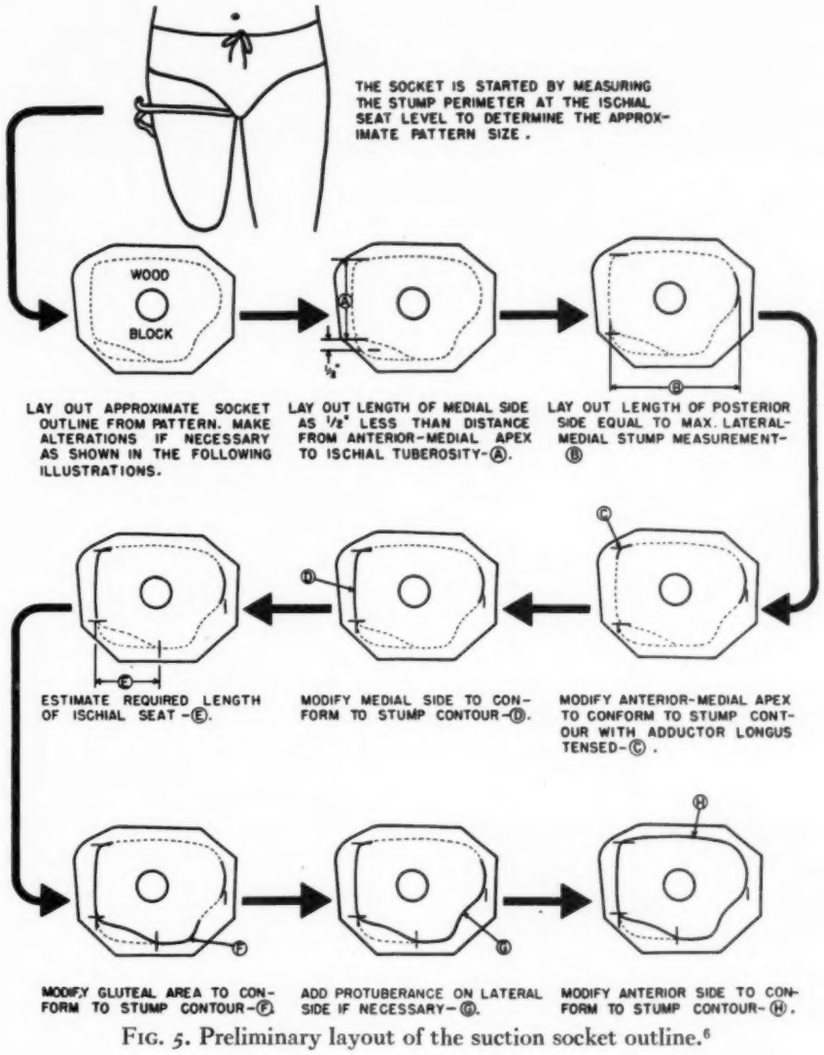
THE SOCKET IS STARTED BY MEASURING THE STUMP PERIMETER AT THE ISCHIAL SEAT LEVEL TO DETERMINE THE APPROXIMATE PATTERN SIZE.
WOOD
BLOCK
LAY OUT APPROXIMATE SOCKET OUTLINE FROM PATTERN. MAKE ALTERATIONS IF NECESSARY AS SHOWN IN THE FOLLOWING ILLUSTRATIONS.
LAY OUT LENGTH OF MEDIAL SIDE AS 1/2" LESS THAN DISTANCE FROM ANTERIOR-MEDIAL APEX TO ISCHIAL TUBEROSITY-(A).
LAY OUT LENGTH OF POSTERIOR SIDE EQUAL TO MAX. LATERAL-MEDIAL STUMP MEASUREMENT-(B)
ESTIMATE REQUIRED LENGTH OF ISCHIAL SEAT-(E).
MODIFY MEDIAL SIDE TO CONFORM TO STUMP CONTOUR-(D).
MODIFY ANTERIOR-MEDIAL APEX TO CONFORM TO STUMP CONTOUR WITH ADDUCTOR LONGUS TENSED-(C).
MODIFY GLUTEAL AREA TO CONFORM TO STUMP CONTOUR-(F).
ADD PROTUBERANCE ON LATERAL SIDE IF NECESSARY-(G).
MODIFY ANTERIOR SIDE TO CONFORM TO STUMP CONTOUR-(H).

FIG. 5. Preliminary layout of the suction socket outline.[6]

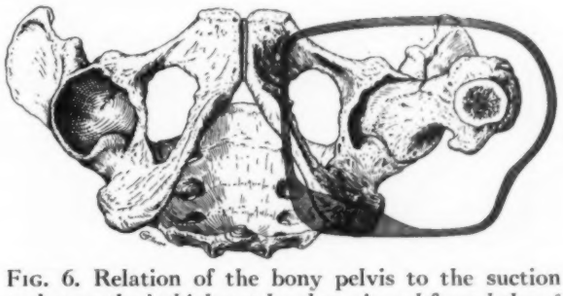

FIG. 6. Relation of the bony pelvis to the suction socket at the ischial seat level as viewed from below.[6]

the stump. An air-escape valve is inserted into the lower portion and over the lower end of the

block a plywood cover with an air seal is glued. This socket is then attached to the usual knee block, knee bolt and lower assembly. Those interested in the details of construction are referred to the third edition of the brochure, with impaired circulation, capillary fragility in the stump, short or long stump or overweight individuals. Of course, the surgeon should accept only the most favorable cases at the start. However, by proper fitting experienced sur-

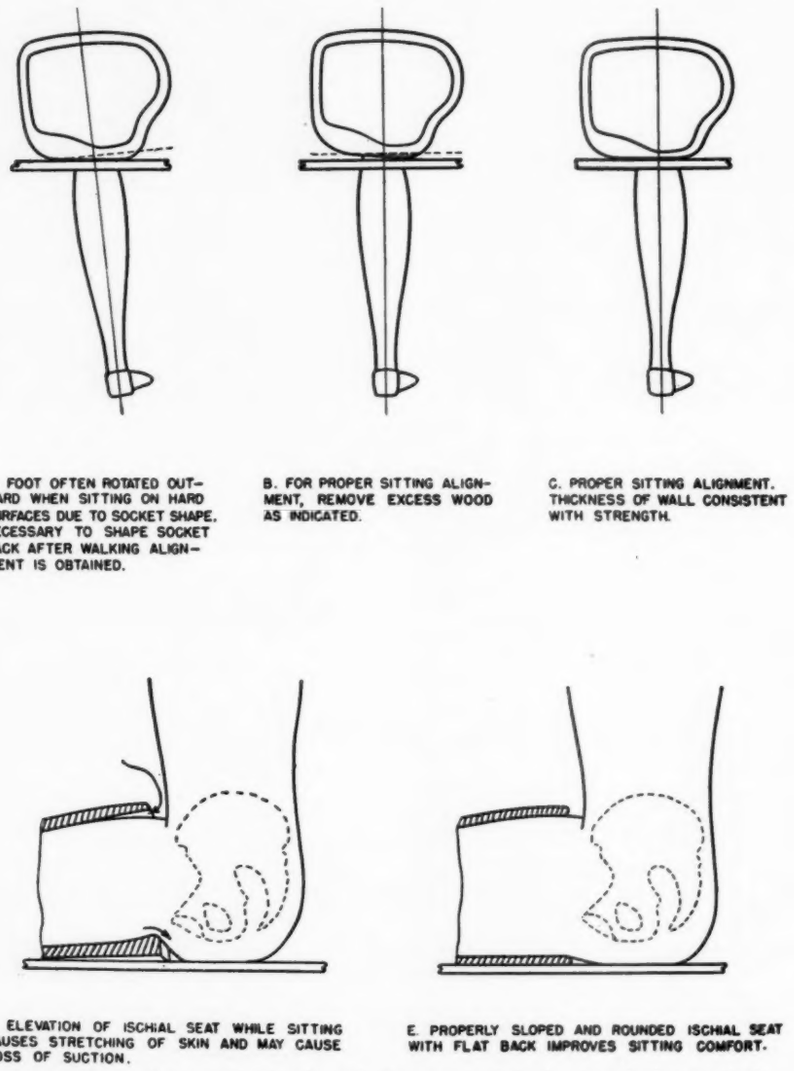
A. FOOT OFTEN ROTATED OUTWARD WHEN SITTING ON HARD SURFACES DUE TO SOCKET SHAPE. NECESSARY TO SHAPE SOCKET BACK AFTER WALKING ALIGNMENT IS OBTAINED.
B. FOR PROPER SITTING ALIGNMENT, REMOVE EXCESS WOOD AS INDICATED.
C. PROPER SITTING ALIGNMENT. THICKNESS OF WALL CONSISTENT WITH STRENGTH.
D. ELEVATION OF ISCHIAL SEAT WHILE SITTING CAUSES STRETCHING OF SKIN AND MAY CAUSE LOSS OF SUCTION.
E. PROPERLY SLOPED AND ROUNDED ISCHIAL SEAT WITH FLAT BACK IMPROVES SITTING COMFORT.

FIG. 7. Shape of the socket back and alignment of the leg in relation to sitting comfort.[6]

"The Suction Socket Above-Knee Artificial Leg."[6] (Figs. 2 to 6.)*

Many surgeons have been fearful of fitting stumps to this prosthesis because of associated injuries of the opposite leg, a bilateral above-knee amputee, deep or adherent scars below the top level of the socket, spurs or bone masses at the lower end of the stump, arterial disease

* Figures 2 to 10 are reproduced through the courtesy of Prosthetic Devices Research Project, University of California.

geons and limb-fitters have fitted stumps of less than three inches (crotch measurement). (Figs. 7 to 10.) Moreover, Gritti-Stokes end-bearing stumps tolerate this prosthesis well if the lower end of the socket is padded with felt. Sometimes, however, long weight-bearing stumps require a lowering of the knee bolt and shortening of the shank.

Specific contraindications exist. Perhaps the most important of these pertain to the psychologic attitude of the patient. It is much easier

to satisfy a prosthesis wearer with a suction socket if the first leg fitted is of this type. All patients selected for this suction socket must be screened. The emotional, negativistic type of amputee should never be changed from a conventional artificial limb. Those amputees harboring low grade osteomyelitis of the femur should be denied the fit of a suction socket. Patients with chronic dermatitis or fungus infection or eczematous rash on the stump should be excluded from wearing the suction socket until cured. The few patients with depressed scars at the top of the thigh should be denied this socket inasmuch as suction could not be maintained.

The importance of follow-up and constant vigilance of the suction socket wearer during his first four to six months cannot be overemphasized. In fact it might be stated that too many surgeons discharge their patients after the fitting of any orthopedic appliance. To alleviate most complaints and to provide better professional service to the veteran orthopedic appliance wearer, the Veterans Administration is setting up Pilot Orthopedic Clinics throughout this continent in twenty-three of its larger regional offices. Five of these already established meet one morning a week under the guidance of an orthopedic consultant. In these clinics will be fitted not only the suction socket wearer but also all orthopedic shoe, brace and prosthesis wearers. As outlets for the field testing of new orthopedic devices these clinics have great potential value.

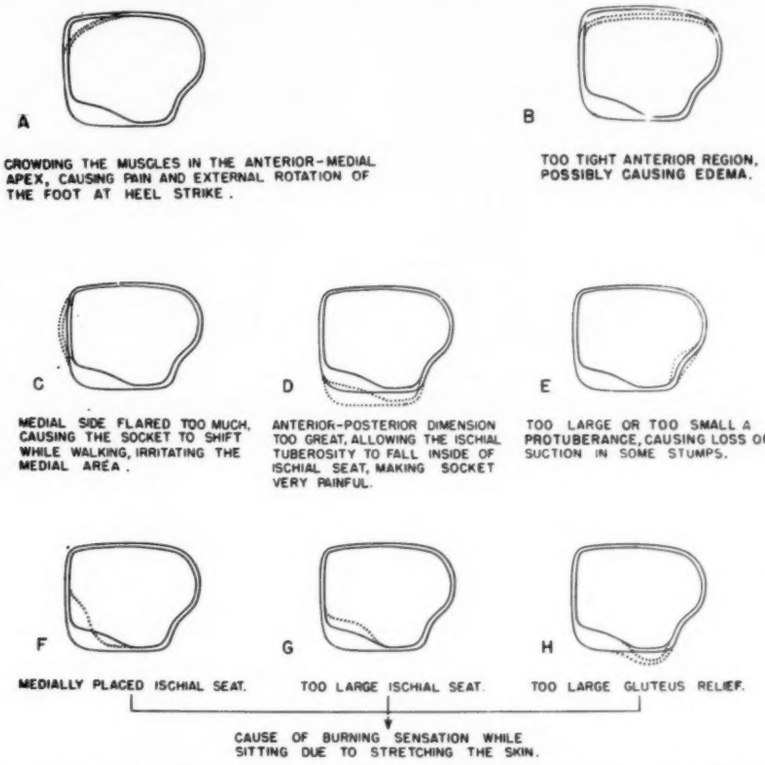
A
CROWDING THE MUSCLES IN THE ANTERIOR-MEDIAL APEX, CAUSING PAIN AND EXTERNAL ROTATION OF THE FOOT AT HEEL STRIKE.
B
TOO TIGHT ANTERIOR REGION, POSSIBLY CAUSING EDEMA.
C
MEDIAL SIDE FLARED TOO MUCH, CAUSING THE SOCKET TO SHIFT WHILE WALKING, IRRITATING THE MEDIAL AREA.
D
ANTERIOR-POSTERIOR DIMENSION TOO GREAT, ALLOWING THE ISCHIAL TUBEROSITY TO FALL INSIDE OF ISCHIAL SEAT, MAKING SOCKET VERY PAINFUL.
E
TOO LARGE OR TOO SMALL A PROTUBERANCE, CAUSING LOSS OF SUCTION IN SOME STUMPS.
F
MEDIALLY PLACED ISCHIAL SEAT.
G
TOO LARGE ISCHIAL SEAT.
H
TOO LARGE GLUTEUS RELIEF.
CAUSE OF BURNING SENSATION WHILE SITTING DUE TO STRETCHING THE SKIN.

FIG. 8. Common errors in fit at top of socket.[6] Errors indicated by dotted lines.

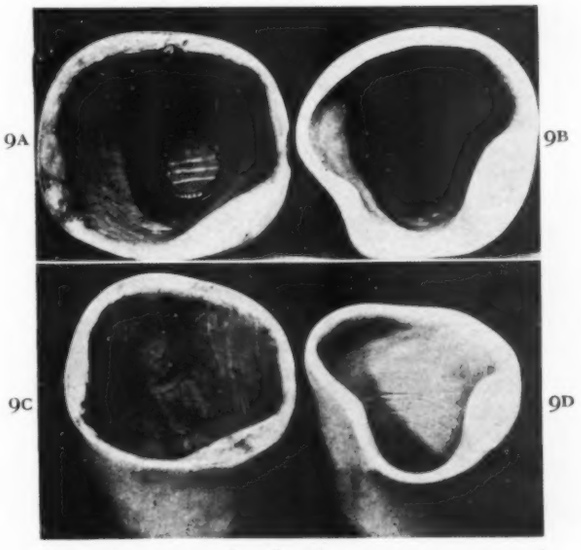

FIG. 9. Suction socket for the same stump; A and C, satisfactory; B and D, unsatisfactory.[6]

SUMMARY

To recapitulate, the tentative conclusions on the current experimental use of the suction socket above-knee prosthesis are as follows:

1. The suction socket above-knee prosthesis is described and found to have been fitted to 211 veteran amputees.

2. Complete failures represent 4.3 per cent of the patients.

3. Inasmuch as 58 per cent of the patients have been wearing this prosthesis for four months or less, the favorable results cannot be construed as conclusive evidence for general approval of the suction socket prosthesis.

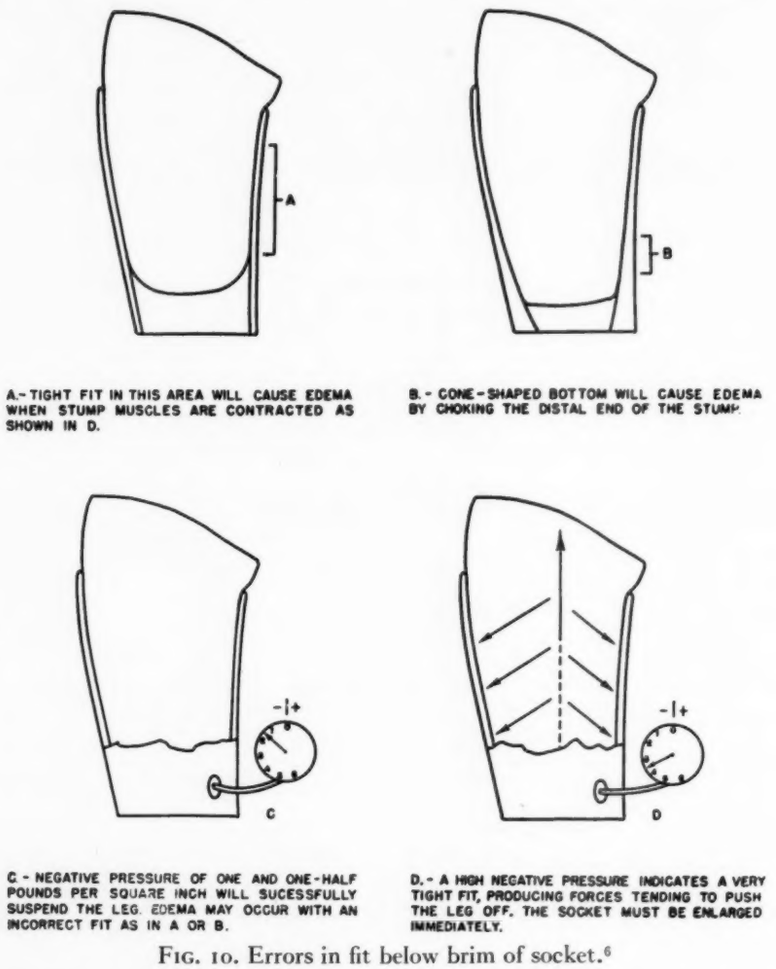
A
B
A.- TIGHT FIT IN THIS AREA WILL CAUSE EDEMA WHEN STUMP MUSCLES ARE CONTRACTED AS SHOWN IN D.
B.- CONE-SHAPED BOTTOM WILL CAUSE EDEMA BY CHOKING THE DISTAL END OF THE STUMP.
-|+
C
D
C.- NEGATIVE PRESSURE OF ONE AND ONE-HALF POUNDS PER SQUARE INCH WILL SUCESSFULLY SUSPEND THE LEG. EDEMA MAY OCCUR WITH AN INCORRECT FIT AS IN A OR B.
D.- A HIGH NEGATIVE PRESSURE INDICATES A VERY TIGHT FIT, PRODUCING FORCES TENDING TO PUSH THE LEG OFF. THE SOCKET MUST BE ENLARGED IMMEDIATELY.

FIG. 10. Errors in fit below brim of socket.[6]

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DISCUSSION OF PAPERS BY DRS. BENNETT AND THORNDIKE

DONALD GORDON (New York, N. Y.): Dr. Thorndike has given a brief but excellent comprehensive resume of the suction socket program in this country. I understand that in Germany it is extensively fitted and has been used since the recent war. After we have learned its advantages and shortcomings we should be able to do in this country what the Germans have accomplished so successfully abroad.

The Veterans Administration by developing and affording the fitting and use of this excellent type of prothesis hopes to make it useful not only to battle casualties but also to civilian amputees. The

Administration hopes to demonstrate to the limb industry the undoubted value of this prosthesis in suitable cases.

I have been afforded an unusual opportunity as a V. A. consultant of observing and examining a group of twenty-eight suction socket wearers fitted in the Research Laboratory of the Prosthetic and Sensory Aids Service at the New York Regional Office of the Veterans Administration. They were a group of wearers fitted in the New York University Experimental Suction Socket Program. The wearers were selected from a group of sixty-eight as suitable to cooperate in further experimental work on shin, knee and ankle activating devices and to permit the two limb-fitters more time to apply and study the application of such devices to the suction socket as well as fitting experimental upper limb prosthesis. All the pilot wearers had been screened by psychologists and their stumps examined by surgical consultants who excluded unsuitable stumps for the various reasons mentioned by Dr. Thorndike.

They were fitted by, or their fitting in a suction socket school supervised by, the two skilled and experienced limb-fitters. Their stump muscles were tested for change in volume, strength and coordination by an excellent physical therapist who trained them in gait, alignment and posture. Their stumps were examined by me when the wearers came in for fitting or with complaints. This was done in the presence of the limb-fitter. I would discuss the medical problems presented and their relation to the fit of the socket. The fitter would in turn explain to me the possible reason for the fit causing the physiologic disturbance and how it could be corrected, made smaller with a liner or given more opening to prevent squeezes as changes in the stump occurred. This relationship is a most necessary one in fitting a suction socket and is to be carried out in planned Pilot Orthopedic Clinics. The limb-fitter would make such changes as were agreed upon and the stump and fit studied after the changes.

A common complaint was skin irritation in the abductor region or crotch which is relieved when a correct fit is obtained.

Skin folds or redundancy above the brim, due to the socket being too small just below the brim to permit the skin to be drawn into the socket, is relieved by opening the socket. A very small change either way or at different points in a well shaped socket accomplishes much for the correction of pressure points and comfort.

Discoloration is due to capillary congestion due to squeeze at the brim or deeper in the socket. Swelling or edema at the end of the stump is due to the same cause or overuse of the limb. I have seen swelling develop in a few hours or only after thirty-six holes of golf. One pilot had only a moderate degree of swelling. It may be obvious only as an increased thickening of the pinched skin. If allowed to persist, it may develop into a bulbous stump with breaking down of the skin. This should not be interpreted as development of musculature as was reported in an outside case.

The treatment is removal of the socket for a period, correction of any squeeze in the socket and elevation of the stump above the heart with the patient lying on his back. Bandaging will aid only if it is done with uniform compression avoiding constriction above the end. I have seen only moderate swelling and discoloration which were quickly relieved by these measures.

Rubbing which irritates the skin may cause increased keratinization which by piling up causes small, hard pimples. If the skin glands become obstructed, cysts occasionally develop. Lack of careful hygiene of skin and disinfection of socket (I have advised ½ of 1 per cent aqueous solution of formalin wiped off with a damp cloth) are apt to produce superficial furuncles if contamination occurs. The stump sock of the conventional limb cannot be disinfected as easily as the suction socket. I have seen an amputee give up using a conventional socket and choose to use a suction type because of furunculosis. A careful exclusion of latent fungus infection should be done when skin irritation becomes persistent. I have seen a most discouraging case for the limb-fitter turned into one in which the patient was a satisfied suction socket wearer by the correction of a yeast fungus, infection.

I have seen very few petechiae or small subcutaneous hemorrhages and these were found due to squeeze or pumping action in a loose socket, occasionally to a defective valve.

The usual discoloration develops as an elliptic area embracing the end and medial aspect of the stump which may fade to a lighter hue as time goes on or may endure as a pigmented area. I have seen no trouble from this nor had any complaints. There are few complaints of pain except that due to sore muscles from fatigue due to prolonged continuous overuse without rest. This is relieved by rest and warm bathing.

I have called attention to a few of the points spoken of by Dr. Thorndike to emphasize that a bad fit causes certain local physical conditions. These in turn increase the fitting problem which in turn adds to the other two. If the vicious cycle is not understood and corrected, mental antagonism develops and cooperation is lost.

To secure a satisfied suction socket wearer calls for tact and surgical judgment in cooperation with a skillful limb-fitter to reassure the amputee during the period of changes in the stump and development of his atrophied muscles until these are able to control the prosthesis. His reward will be the avoidance of an irritating abdominal belt

with hinge or shoulder harness and an inconspicuous limp in a comfortable, controllable limb.

It is quite apparent that by having beginners in its fitting see others using it successfully and talking with them makes them aware of its advantages and is most helpful in gaining their cooperation until a correct fit is obtained.

It has been a great privilege to be permitted to work in close contact with Dr. Thorndike's Service which affords promise of such an efficient aid in rehabilitating the above-knee amputee.

Louis G. Herrmann (Cincinnati, O.): I realize that Dr. Bennett did not have the opportunity to discuss the problem of the care of the large mixed nerves of an extremity at the time of amputation. We are agreed that any injury to these large mixed nerves at the time of amputation may lead to severe phantom limb pains or chronic aching pain in an amputation stump.

It has been our opinion for a long time that centrally conducting axons carry abnormal impulses to the higher nerve centers and give rise to the syndrome which is called phantom limb pain. The time to do most for such pain is at the time of amputation and not six or eight months afterward.

Before this Association some years ago we reported our own experiences with the management of large mixed nerves at the time of amputation. We expressed the opinion that no injury to a mixed nerve should be permitted at the time of amputation whether that injury is by a small, hollow needle with novocain, alcohol or any other similar solution in it. We believe that the best way to reduce the incidence of phantom limb pain and pain in the amputation stump is to use a non-absorbable ligature and tie it tightly around the otherwise normal nerve above the site of amputation so that a band of scar tissue will develop at the point of pressure necrosis. The perineurium then seals over the end of the nerve without the formation of a neuroma.

Whether or not neuromas are actually responsible for phantom limb pain is disputable. I believe we can reduce the incidence of phantom limb pain by more careful attention to the large nerves at the time of amputation of the extremity.

With respect to Dr. Thorndike's paper, I should like to ask him one question. He did say extensive arterial disease was a contraindication to suction-type stumps? I think the suction socket is a real advance. We see a great number of patients who have extensive arterial disease or arteriolar disease and I would like to hear him say something about the indications for the suction stump in that type of patient.

Joseph E. J. King (New York, N.Y.): I should like to ask a question of Dr. Bennett, Dr. Thorndike, Dr. Mayfield or anyone else present. Dr. Bennett spoke about the phantom limb pain but I should like to ask anyone in this audience if he actually knows what to do for it. When the patient comes to you, what do you say to him? If a person needs resection of his stomach or an appendectomy, one can readily state, "Yes, we know what to do" but I have never known what to do for the phantom limb. A number of people with whom I have talked say that they usually try to get them to go to someone else.

Arthur R. Metz (Chicago, Ill.): Dr. Bennett has discussed a number of points to be considered in amputations as a group calling special attention to amputations through the foot.

It is good practice to maintain whenever possible a weight-bearing surface in doing a foot amputation. Whenever possible the flexor tendons should be preserved thus giving the patient a stump that he can control and walk on. In case too much of the foot is injured to preserve the flexor tendons of the ankle and there is still padding over the os calcis, Pirogoff's amputation should be performed which consists of ankylosing the os calcis to the end of the tibia and gives the patient a weight-bearing heel to which a satisfactory appliance can be fitted. Patients with this type of amputation get so they can carry on in a very active manner and do regular work.

In amputations below the knee it is desirable to have a stump 4 to 5 inches long as determined by measuring the tibia on x-ray films. In addition a more comfortably fitting stump can be made if the entire fibula is dissected out at the time of amputation and the perineal nerve severed high up so as to avoid pressure in the socket.

A stump of only 1 to 2 inches of tibia will be enough to give the patient knee action which is the important part in an amputation below the knee. An effort should always be made to preserve knee joint action in any amputation below the knee.

Dr. Bennett has pointed out many practical points to be observed in amputations in general.

R. J. Bennett (closing): Dr. King mentioned the phantom limb. I have gone over the literature thoroughly and I have attempted to do some experimental work on this phantom limb. However, these are only subjective symptoms and it is impossible to do experimental work but we go by the signs and symptoms of people who have had phantom limbs.

You will find several cases of phantom limb in the literature. In one particular case one man had his arm taken off while in the air force during the last war; he returned and they had quite a time with him. He insisted on going back with his unit and he was not allowed to go. I believe the story goes that he had a particularly painful phantom limb. He was really disabled with it. Finally, a report came through to the effect that he was allowed to return to his unit and the phantom limb quieted down. He has not had any trouble since.

I think, undoubtedly, the psychiatric side plays

a part in phantom limb. By giving the procaine intravenously whereby we will get the local, regional and central wiping out of these impressions, we may be able to find out something. I do know that procaine has been used intravenously in the most painful cancerous conditions in which the patient has been absolutely unable to stand the pain and it has been wiped out by this intravenous injection.

AUGUSTUS THORNDIKE (closing): Relative to Dr. Kennedy's remarks from Dr. Gordon, I want to recall to your minds that the twenty-eight patients whom he examined were some of the very first that were fitted and they had every known complication, I think. The fit was too tight at that time but we have salvaged twenty-eight by follow-up and careful adjustment so that they are now considered satisfactory.

Remember, the patients in the series that I reported are all old amputees. They formerly had been on a temporary or permanent leg of the Army or Navy. They have had to be retrained entirely and many of them have had to come back innumerable times to be fitted and adjusted correctly.

Dr. Herrmann mentioned the phantom limb pain and also Dr. King. We have a research project under way now that shows some promise. I am not able to say very much about it but perhaps in another year we will have some results we can talk about. One of our research contractors is working on that problem now.

We are not prepared to say a great deal about the problem of arterial disease and contraindication for suction socket at this time but we have fitted the suction socket to some definite arteriosIcerotic individuals, veterans of World War I. These veterans seem to be very happy and delighted that nothing has happened; they have worn it over a period of six months. We cannot say it is right in every respect. We do not know how far even these cases will go but it is promising.

I was interested to hear Dr. Bennett mention procaine intravenously. I am personally a little skeptical but I would like to see somebody report a series of cases. We are open-minded; we do want to lick this phantom limb problem.

I want to thank the discussors for what they have said and I hope that we may be able to report further on other developments in this research program on prosthesis.

LOUIS G. HERRMANN (Cincinnati, O.): I would like to bring up another question. I told you that we were interested in the prevention of phantom limb pain because we have tried almost every known procedure to relieve pain and have not been uniformly successful. Dr. Thorndike has also indicated that it is one of the big problems in the management of both severe trauma to an extremity as well as amputations following arterial disease, particularly arteriosclerosis. I should like to have a morning devoted to the problem of pain in an extremity sometime in the near future in this organization so that we ean discuss all the failures (psychiatric and neurologic) and also the technical side of the problem of the relief or prevention of phantom limb pain.

EARLY AMBULATION FOLLOWING INTERNAL FIXATION IN ARTHRODESIS OF THE SPINE

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Minot, North Dakota

IT is approximately forty years since the report of the first successful arthrodesis of the spine appeared in the literature. The operation was conceived as a means of permanently immobilizing a tuberculous spine and the attendant advantages of surgical arthrodesis soon were apparent. Time has proved the efficacy of the operation whose scope has been enlarged to include any condition that may be expected to benefit from immobilization. Few would contest its value in properly selected cases.

Improvement in surgical technic, increased knowledge of blood typing and compatibility, appreciation of the value of generous use of whole blood transfusions in combatting shock and introduction of intrathecal and intratracheal anesthesia and of anticoagulants and antibiotics have removed most of the hazards.

A major deterrent to a more general use of surgical arthrodesis, however, is the patient's unwillingness to submit to, or his economic inability to withstand, several months of postoperative immobilization in a plaster of paris cast in the recumbent position.

Appreciation by the medical profession of this state of affairs is attested by the appearance in the literature of various methods of internal fixation of the spine to promote early ambulation. King[1] described the use of screws to transfix the apophyseal joints and immobilize them after first performing a Hibbs type of arthrodesing operation. The postoperative period of immobilization is reduced by King to three weeks. A plaster cast is used in conjunction. This operation has been widely accepted and various authors have commented favorably upon the results they have obtained.

Although screw transfixion of the apophyseal joints has been stated to offer inadequate support, no concrete evidence to substantiate this criticism has been presented. King in his original report states that when the operation is performed upon a cadaver in the prone position and a hook placed under the fifth neural arch and upward traction made with a rope passing over a ceiling pulley the body can be raised without the transfixion giving way. This would appear to refute the aforementioned criticism.

Previous evaluations of the success of the procedure have been concerned with evidence of fusion of the apophyseal joints. King[2] reports satisfactory fusion in 90 per cent of the forty-four cases he traced. This is based upon roentgenographic evidence of demonstrable movement of the apophyseal joints in oblique films of neutral, hyperextension and hyperflexion positions.

A review of the cases of arthrodesis of the spine in the New York Orthopaedic Hospital[3] during the ten-year period from 1938 to 1948 demonstrated an over-all pseudarthrosis of 16 per cent. With the usual Hibbs procedure with routine postoperative immobilization of several months, pseudarthrosis was 14 per cent at the lumbosacral joint whereas with the use of screw fixation it was 12 per cent. The comparison was less favorable at the fourth lumbar interspace. In this latter location the routine Hibbs fusion and immobilization resulted in a 23 per cent pseudarthrosis as compared with 52 per cent when screws were used.

Evidence of fusion of the spine based upon roentgenographic studies is of great practical and academic interest. Relief from symptoms and roentgenographic evidence of arthrodesis of the apophyseal joints are not closely correlated, however. King reported three patients unrelieved clinically with positive roentgenographic evidence of fusion and three patients in whom the opposite was true. Haggart[4] states that visualization of the apophyseal joint space roentgenographically is compatible with clinical arthrodesis as verified by findings at the operating table.

Relief from symptoms for which arthrodesis is performed is a practical evaluation of its success. Other data of equal practical importance are as follows: Can the patient return to his original occupation? Is he able to perform a full day's work? How much time has been lost? In this study a questionnaire was formu-

lated in such a way that the patient had to answer yes or no. The results of this questionnaire are seen in Tables I to IV. Although ninety-two patients have been operated upon, only fifty-two who responded to the questionnaire and whose postoperative period is one year or longer are included.

TABLE I
BACKACHE

Pain	No. of Patients	Per cent
None	27	52
Slight	16	30
Moderate	9	18
Severe	None	None

TABLE II
LEG ACHE

Pain	No. of Patients	Per cent
None	39	75
Occasional or mild	12	23
Severe	1	2

In each instance a Hibbs type of arthrodesis first was accomplished. Vitallium screws were then passed across the apophyseal joint. An attempt was made to transfix the facetial joints and enter the pedicle, a feat that can be accomplished more than half the time. Screw lengths up to 1½ inches thus may be used. In no instance has it been necessary to remove a screw because of nerve pressure and there have been no complications arising from the use of screws. Bone sufficient for grafting is obtained from the exposed spinous processes and sacrum. Donor site pain occasionally experienced when bone is removed from the iliac crest and fracture of the leg occasionally experienced when the graft is removed from the tibia are eliminated.

TABLE III
CONDITION OF BACK

Condition	No. of Patients	Per cent
Strong	24	46
Slightly weak	21	42
Moderately weak	7	12

The marked reduction in postoperative pain is striking and permits early ambulation. Originally the patients were kept in a recumbent position for three weeks as advocated by King. Among the first patients operated upon was a husky, former professional football player. Eight hours after the operation he got out of bed and walked around the hospital corridors. He left the hospital on the fourth postoperative day and drove his automobile 600 miles in the next three days. Twenty days later he began coaching a championship college football team. He has done all types of athletics and states he is entirely free from back and leg ache. As a result of this experience other patients have been urged to follow his example. To date nothing has occurred to discourage the program.

SUMMARY

The results obtained in fifty-two patients treated with Hibbs spinal fusion plus internal

TABLE IV

Diagnosis	No. of Cases	Day Ambulatory	Postoperative Day Discharged	Returned Same Job No.	Returned Same Job Per cent	Can Do Full Day's Work No.	Can Do Full Day's Work Per cent	Length of Disability (Mo.)
Compression fracture with or without disc	5	7	16	3	60	3	60	2½
Subluxation of facets with or without disc	9	6	12	8	90	8	90	4
Degenerative arthritis with or without disc	14	12	15	13	90	13	90	2
Spondylolisthesis with or without disc	7	9	13	6	75	6	75	3
Normal spine x-ray with disc	13	8	13	13	100	13	100	2
Normal spine x-ray without disc	4	9	13	4	100	2	50	5
Workmen's compensation cases	14	7	11	11	71	12	85	3
Total group	52	9	12		90		86	3

fixation of the apophyseal joints with Vitallium screws are reported. There is a marked reduction in postoperative pain. On the average patients are ambulatory on the ninth postoperative day and leave the hospital on the twelfth. Recent experience indicates these figures may be materially reduced.

Of the patients 98 per cent have returned to their same occupation; 86 per cent are able to do a full day's work; 80 per cent are entirely relieved or at most have only a slight backache; 46 per cent state their backs feel strong and 75 per cent are entirely relieved of leg ache. None have a severe backache and one has continued to have a severe leg ache.

The poorest results are among the four who have a typical disc syndrome with normal roentgenograms of the spine and in whom no retropulsed nucleus pulposus was demonstrated at operation. Results are better among those patients who have been operated longest indicating that fusion may require many months. There have been no complications directly attributable to the use of screws and in no instance has it been necessary to remove them.

CONCLUSION

1. Internal fixation by greatly reducing postoperative pain and immobilizing the spine until bony ankylosis can occur permits early ambulation with all its attendant physiologic advantages.

2. In addition to the physiologic advantages of early ambulation there are the equally important economic advantages, namely, marked reduction of hospital expense and elimination of the psychic trauma associated with prolonged hospitalization upon reduced income, dwindling savings and long periods away from work.

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COMMINUTED COLLES' FRACTURE*

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Sayre, Pennsylvania

IN spite of the vast knowledge that has accumulated concerning every aspect of Colles' fracture, it is surprising that the incidence of malunion with its attendant pain, loss of function and deformity remains high. The causes of malunion in this fracture are well understood yet a widespread concerted effort to prevent this complication has not apparently been made. An indifferent attitude has developed in regard to this deformity in spite of our knowledge that the best functional and cosmetic results are directly proportional to the excellence of the anatomic result.

It is the purpose of this paper to discuss one of the frequent causes of malunion in Colles' fracture, comminution, to review a method of treatment of this type of fracture and to present a series of patients with comminuted Colles' fractures treated by this method.

The frequency of comminution in this fracture is witnessed by A. W. White who reported an incidence of 74 per cent of comminution in sixty-six patients. The amount of comminution varies from gross shattering of the distal radial fragment with displacement of the multiple extra- and intra-articular fragments in various directions to the less extensive crushing limited to the dorsal and lateral cortices of the radial fragments at the site of fracture. In any case the fragments show a varying degree of instability following reduction and splinting by ordinary means. In moderate and severe cases this instability is perfectly obvious in the original x-ray films but it is in the numerous lesser comminuted fractures so common in elderly people that unstableness may be overlooked unless close attention is paid. In the latter group the dorsal crumpling of the fragments is often mistaken for impaction of intact cortices. However, the comminution and crushing, which in a sense amounts to loss of substance, will generally become evident in reduction roentgenograms after traction has been applied or soon thereafter when loss of reduction occurs due to the lack of intact bone dorsally and laterally.

TREATMENT

No one denies that this fracture can generally be reduced easily by longitudinal traction combined with manual pressure and molding but there is disagreement as to the proper method of retention. It is agreed that comminuted fractures of long bones in other regions usually require special immobilizing precautions to maintain reduction. The reason that comminuted fractures of the distal radius should be exceptions to this belief is not entirely understandable. In severe cases of comminution the author is in accord with Bohler, Cotton, Darrach and others that reduction cannot be maintained by the application of a plaster cast alone; but it is further thought that particular means of immobilization should be used in many of the lesser degrees of comminution in order to prevent recurrence of deformity and malunion.

Bohler pointed out at least fifteen years ago that comminuted Colles' fracture could be maintained in reduction by using two transfixion wires and by applying axial traction and a plaster cast to include the wires. This procedure is simple, effective in preventing malunion and applicable to both young and old alike. It is my conviction that this method has not received the merit it deserves and has not been employed widely enough in the treatment of these patients.

The decision to use this method of splinting should be made immediately in cases of severe and moderate comminution. However, in cases in which there are milder degrees of comminution the decision may be more difficult to make because it may be possible to maintain reduction by a very efficient plaster cast. If a plaster cast or plaster splints alone are used and prove ineffective in preventing malposition, the double wire method can be adopted. Early and repeated postoperative roentgenographic films should disclose the loss of reduction so that the Kirschner wire method of retention may be used within the first seven to fourteen days

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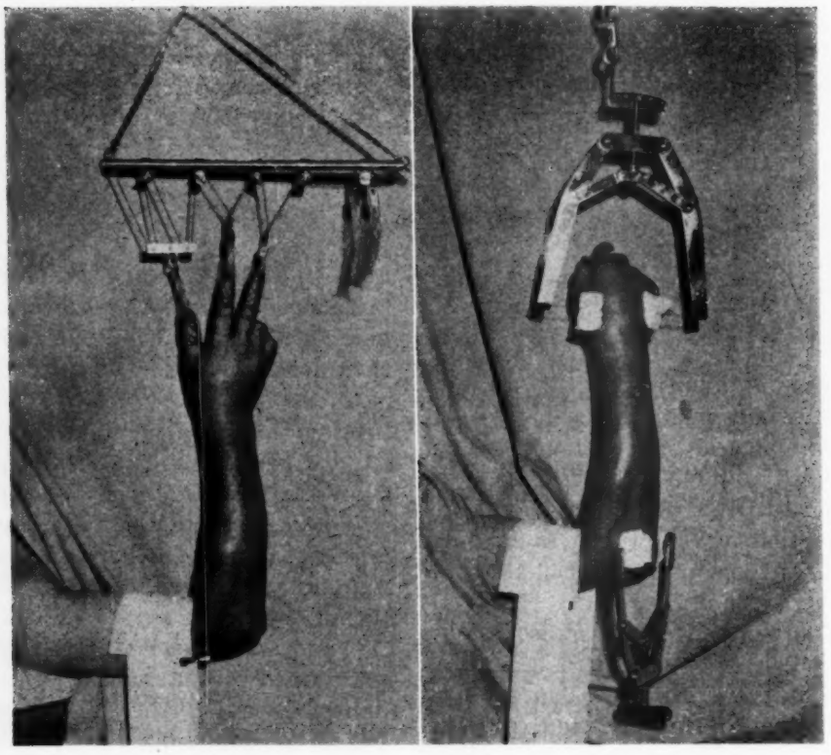

1 2

FIG. 1. The thumb, index and middle fingers are placed in finger traps and the upper extremity is suspended by the traction apparatus. The counter-traction loop is shown just above the elbow. The elbow, forearm, wrist and hand are prepared surgically and draped.

FIG. 2. The Kirschner wires have been inserted and the traction bows applied. The finger traps are removed and the distal bow is suspended. The major displacement is corrected by axial traction alone. Gentle manipulation completes the reduction.

after injury. Delay in making the decision to correct and splint properly a slowly increasing malposition at this stage of treatment is frequently the cause of later malunion.

Technic. Usually general anesthesia is employed and the thumb, index and middle fingers are placed in finger traps suspending the upper extremity with the wrist in neutral, the forearm in mid-position, the elbow in 90 degree flexion and the shoulder in 90 degree abduction. (Fig. 1.) Counter traction is applied by means of a loop of 4 inch bandage passed around the arm just above the elbow and extending to the floor where it is fixed by the operator's foot. The amount of traction can be varied as the case demands. It is to be emphasized that this longitudinal traction will correct most of the displacement and that very little further manipulation is necessary to bring about complete reduction. (Figs. 4B and 5B.) Forceful manipulation, including rocking of the fragments to free the impaction, is unnecessary and unwise as it often causes more crushing and comminution, particularly in the more atrophic bone of the elderly patient. A Kirschner wire, $\frac{1}{16}$ inch (.06 inch) in diameter, is inserted transversely through the bases of the second to fifth metacarpals and a second wire inserted transversely through the olecranon process about 1 inch distal from its tip. Traction bows are applied to the wires, the distal bow is suspended and the finger trap suspension removed. (Fig. 2.) The distal radial fragment is then gently manipulated so as to correct any residual dorsal tilt and displacement, radial deviation and supination twist. If there is residual displacement of major fragments, they can be molded together manually. The wrist is held in ulnar deviation and slight palmar flexion and the forearm in mid-position; portable x-ray films are then taken. When the reduction is excellent, a slightly padded, circular plaster cast incorporating the wires is applied from the axilla to the proximal flexion crease of the palm with the

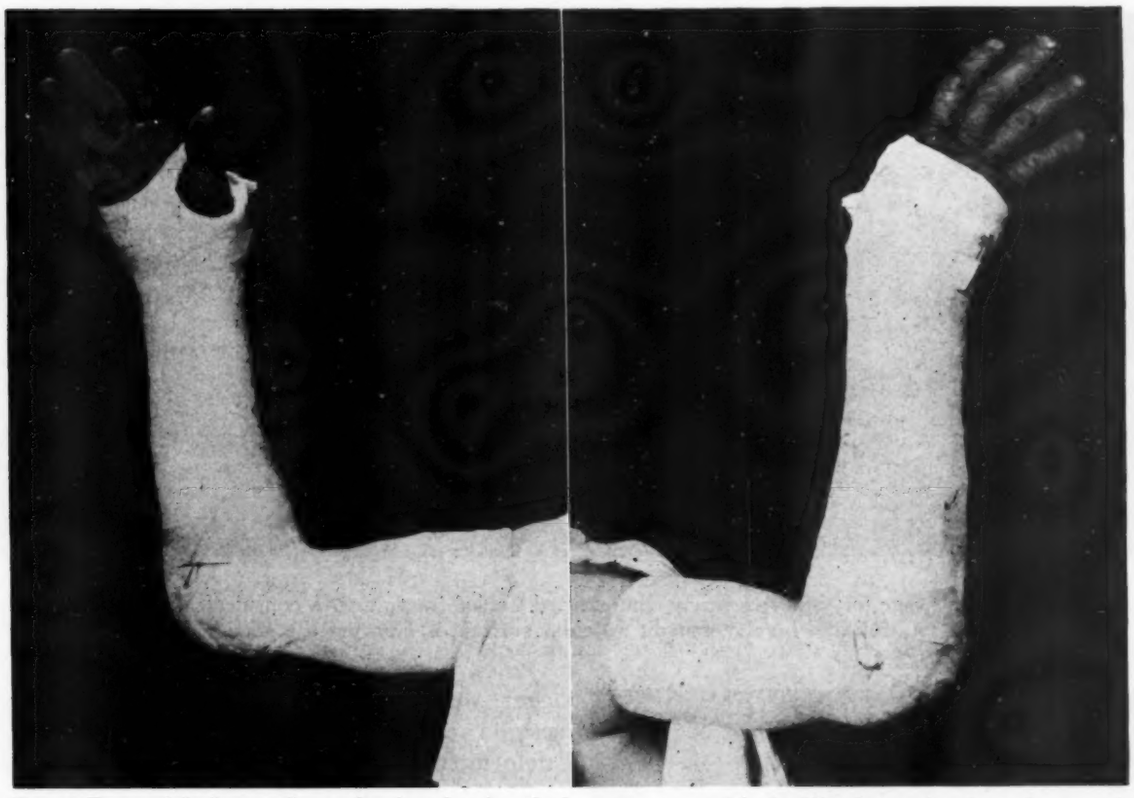

FIG. 3. Forty-eight hours after reduction showing the long arm cast with the Kirschner wires bent down and secured by adhesive tape; complete shoulder, finger and thumb motions are done regularly.

elbow, forearm and wrist in the positions mentioned. With double wire fixation pronation has not been necessary to prevent recurrence of supination of the distal radial fragment. The thenar eminence is completely freed for full thumb motions.

Postoperative Care. The extremity is suspended by the distal traction bow for twenty-four to thirty-six hours to combat swelling. Roentgenograms are taken soon after reduction and are repeated at suitable intervals during the convalescence to be certain that reduction is being maintained. The bows are removed as soon as the cast is well solidified and the protruding wires are bent down and secured with adhesive tape for possible future use. (Fig. 3.)

Immediately after recovery from anesthesia full motions of the fingers are insisted upon for five to ten minutes of each waking hour. The shoulder is exercised through a full range of motion twelve times daily. The importance of these exercises can not be overemphasized and it is essential to be certain that they are being done properly and completely at each subsequent visit of the patient.

The wires are removed four to six weeks after reduction in young adults but never before six weeks in the older patients. After removal of the wires a short or long arm cast is applied until union is firm both clinically and roentgenographically. Eight weeks of immobilization have been found necessary in these comminuted fractures because solid union occurs slowly, particularly in the zone of bone crushing. Discontinuing immobilization before this time adds a grave risk of redisplacement.

As soon as the elbow, forearm and wrist are freed, intensive hourly active motions are begun. It is to be stressed that the author has not found that the elderly patient develops persistent stiffness of the elbow or forearm as a result of such a cast nor is there any difficulty with the finger or shoulder motion if the patient will carry out the exercise program.

Motion and other forms of physical therapy applied to the wrist joint before the fracture is solidly united are mentioned only to be condemned as valueless and dangerous.

Outpatient visits after reduction are of great importance in attaining good results and these patients should be followed rather closely for at least six months. A prolonged disability has not been noticed in these patients. The usual patient shows prompt and progressive recovery

4A 4B

FIG. 4. A, T. C., male, age forty-four; severely comminuted Colles' fracture with considerable radial shortening, posterior and radial rotation and involvement of articular surface; B, showing the good reduction obtained by traction alone.

FIG. 4. C, T. C., thirty months postreduction; this is an excellent result from every aspect.

of function after the splinting has been discontinued.

Review of Cases. From March 15, 1946 to March 15, 1949, a three-year period, 123 patients with 124 Colles' fractures have been treated at the Guthrie Clinic and Robert Packer Hospital. The patients to be reviewed in this series consist of thirty-one patients with thirty-two comminuted Colles' fractures (25 per cent) who were considered sufficiently unstable to warrant treatment by the double Kirschner wire technic. Eight of these fractures (25 per cent) were treated by manipulation and application of cast primarily but recurrence of deformity early in the convalescence plus the comminuted nature of the fracture prompted remanipulation and the use of wires to maintain reduction. This recurrence occurred in spite of using a cast from axilla to metacarpophalangeal joints with the wrist in moderate palmar flexion and ulnar deviation and the forearm in full pronation.

TABLE 1

AGE INCIDENCE OF COMMINUTED COLLES' FRACTURE IN DECADES

Decade	Cases (No.)	Per cent
20–29	5	16
30–39	3	10
40–49	4	13
50–59	5	16
60–69	6	19
70–79	6	19
80–89	2	7
Total	31	100

Age and Sex. The ages of the patients varied from twenty-one to eighty-three, 45 per cent being over and 55 per cent under sixty years of age. (Table 1.) Of the patients 64 per cent were females and 36 per cent males. It is of interest that seventeen (89 per cent) of the

nineteen patients over the age of fifty were females whereas nine (75 per cent) of the twelve patients under the age of fifty were males.

Etiology. As one would expect, the trauma causing the fracture was much more severe in those patients under fifty years of age while over this age the injury as a rule consisted of a fall upon the outstretched hand.

Roentgenologic Studies. The original x-ray films were studied thoroughly and the following features are noteworthy:

1. *Severity of Comminution and Displacement:* In this regard the fractures were classed as severe in fifteen, 47 per cent (Figs. 4A and 5A), moderate in fourteen, 44 per cent, and mild in three, 9 per cent. However, it is to be stressed that these thirty-two patients represent the most markedly comminuted and displaced fractures of the entire group of 124 Colles' fractures. Even the mild cases are potentially severe malunions.

2. *Involvement of the Radiocarpal Joint:* One or more fracture lines entering the radiocarpal joint with varying amounts of displacement of the articular fragments were present in nineteen patients (59 per cent). No involvement of the joint could be seen in thirteen instances (41 per cent).

3. *Degree of Posterior Rotation of Distal Radial Fragment:* The amount of posterior tilt is one index of displacement that can be measured in the roentgenograms but it does not necessarily indicate the seriousness of the malposition as the posterior rotation can be mild in an otherwise markedly comminuted and displaced fracture. The normal volar tilt of the distal radial articular surface is about 10 degrees. The amount of dorsal tilt in this series ranged from 15 to 60 degrees with an average of 36 degrees. One patient had a volar tilt of 7 degrees.

4. *Degree of Radial Rotation of the Distal Radial Fragment:* The amount of radial rotation is another displacement which is usually measurable but which does not necessarily indicate the seriousness of the displacement. The distal radial articular surface normally faces ulnarward or medially at an angle of about 25 degrees. Because of the severe displacement this angle could not be measured in four patients but in the remaining twenty-eight it ranged from 5 to 27 degrees and averaged 16 degrees.

5. *Fracture of Styloid Process of Ulna:* This process was fractured in twenty-four patients (75 per cent) and was not fractured in six patients (19 per cent). A partial fracture of the head of the ulna including the styloid process was present in two patients (6 per cent).

6. *Shortening of Radius:* The amount of radial shortening was classed as severe in thirteen patients (41 per cent), moderate in eleven patients (34 per cent) and mild in eight patients (25 per cent). In the milder cases of comminution the shortening often effectively hides the posterior comminution which becomes evident only after full radial length has been restored by traction.

Complications. Complications in this series of patients have been uncommon and consisted of:

1. *Infection:* One patient had two short episodes of inflammatory reaction in the region of the fifth metacarpal at the site of a previous wire. In both instances the inflammation subsided rapidly under conservative therapy. No suppuration resulted and no sequestration could be seen in the roentgenograms.

2. *Sudeck's Atrophy:* One patient developed mild, post-traumatic, acute bone atrophy about one week after manipulative reduction and completely recovered in the next five weeks.

3. *Median Neuritis:* Symptoms of a mild median neuritis were noted soon after injury in one patient and complete recovery occurred in ten weeks.

4. *Periarthritis of the Shoulder:* Three elderly patients had mild periarthritis of the shoulder of the affected extremity. In two of these three patients the condition was asymptomatic and was discovered only by routine examination of this joint some time after reduction. At times it is difficult to impress the patient of advanced years with the importance of exercise to prevent this complication.

5. *Death:* One patient, fifty-seven years of age, suddenly died on the fifth postoperative day of a cerebrovascular accident or coronary occlusion. Autopsy was refused.

RESULTS

In order to give an accurate result it was thought that at least six months must elapse from time of reduction to appraisal of the case. Twenty-four patients with twenty-five Colles' fractures have been followed up from six to thirty-six months after reduction. The remaining seven patients consist of six who have been

5A 5B

FIG. 5. A, W. C., male, age twenty-one; severely comminuted Colles' fracture with marked posterior and radial tilt, posterior displacement, radial shortening and displacement of articular fragments; note the finer crushing of the posterior cortex of the distal radial fragments (bilateral case); B, showing the excellent reduction by traction alone.

FIG. 5. C, W. C., sixteen months postreduction; the subjective and objective results are good but the roentgenographic result is only fair. Kirschner wires of small diameter bowed in the cast after reduction and allowed moderate recurrence of radial shortening.

followed up less than six months and one patient who died.

The subjective end results were secured by direct questioning in all cases. The patients with excellent results have no symptoms; they consider the upper extremity normal in every regard and are completely rehabilitated. The patients with good results have only very slight symptoms and otherwise consider the extremity normal and are completely rehabilitated. Of these patients 81 per cent obtained an excellent or good result and there were no poor results from a symptomatic standpoint.

The objective end results were obtained from the final clinical examination of the extremity. The patients with excellent results have no or only slight variations from the normal as regards deformity, range of joint motion, muscle power, etc. The patients with good results have slight abnormalities in these regards. Seventy-six per cent of these patients had an excellent or good result and there were no poor results from an objective standpoint.

Roentgenologic. The final x-ray films were carefully reviewed and the results classified in the twenty-five wrists. No patient was considered absolutely normal from roentgenologic aspects. Every patient had solid bony union and there was no instance of moderate or severe malunion. Excellent results showed almost normal configuration of the wrist with no radial shortening at the radio-ulnar joint, smooth articular surfaces, no or very minor degrees of radial rotation and posterior rotation of the distal radial fragments; there was no other significant abnormality. (Fig. 4C.) Patients with good results had a slight change from the normal anatomy. Seventy-two per cent of the patients had excellent or good re-

sults and there were no poor results from a roentgenographic standpoint.

Twelve wrists (48 per cent) had some recurrence of posterior tilt of the distal radial fragments. This tilt ranged from 2 to 13 degrees and averaged 6 degrees. Ten wrists (40 per cent) showed a volar tilt ranging from 2 to 12 degrees and averaging 5 degrees. In three patients the distal radial articular surface was in neutral, exhibiting neither a volar nor dorsal tilt.

TABLE II

END RESULTS IN TWENTY-FOUR PATIENTS WITH TWENTY-FIVE COMMINUTED COLLES' FRACTURES

Result	Cases (No.)	Per cent
Excellent	8	32
Good	11	44
Fair	6	24
Poor	0	0
Total	25	100

In the twenty-five wrists the distal radial joint surface faced ulnarward at an angle varying from 15 to 27 degrees and averaged 22 degrees.

Recurrence of some degree of radial shortening was the most frequent cause for downgrading the roentgen result. (Fig. 5c.) In the twenty-five wrists thirteen (52 per cent) showed no radial shortening, three (12 per cent) had mild shortening and nine (36 per cent) revealed moderate recurrence of the radial shortening. It should be pointed out that five of these nine patients do not notice any wrist deformity and four notice a slight prominence of the ulnar head. On clinical examination in each instance the radial shortening was classified as mild, the radial styloid process being below the level of the ulnar styloid process but not to a normal degree. This deformity can be prevented as noted in the Comments.

End Results. By combining the subjective, objective and roentgenologic results in the twenty-five comminuted Colles' fractures, reasonably accurate end results can be determined. The average follow-up period is 14.3 months. Table II depicts the end results in these patients. Seventy-six per cent obtained excellent or good results and there were no poor results.

COMMENTS

The end results speak for the success of the Bohler method in treating comminuted Colles' fractures. No moderate or severe malunion occurred in this series of patients in spite of their representing the most severely comminuted and displaced fractures of the entire group of 124 Colles' fractures. The absence of malunion may account for the lack of development of any case of traumatic arthritis which, however, may be a later complication in some of these patients. In this regard it is of interest that there was no significant difference in the end results in those patients with fracture lines entering the radiocarpal joint as compared to those without involvement of this joint.

The recurrence of a part of the original radial shortening in 48 per cent of the patients can be explained on an error in application of Bohler's technic. In each case the resultant deformity was mild as judged both by the patient and by clinical examination. However, these patients had inferior end results when compared to those without shortening. In every case in which the roentgenogram indicated a moderate recurrence of radial shortening a Kirschner wire of small diameter had been used and the wire had not been prevented from subsequent bowing in the cast by applying screw caps or lock nuts to the ends of the wires after the plaster had set. Radial length was then lost in the postreduction period due to the instability of the fracture and the lack of tautness of the wire (Fig. 5c.) This complication can be prevented by using Kirschner wires of $\frac{1}{16}$ inch diameter as described under Technic or by using the lock nuts on wires of smaller diameter. In eleven cases in this series in which the larger wire was utilized no significant radial shortening occurred. (Fig. 4c.)

Although every effort should be made to reestablish the normal volar tilt of the distal articular surface, a few degrees (up to 10) of posterior rotation did not affect the result adversely. The results were not influenced by the presence or absence of bony union of the ulnar styloid process.

It is still frequently expressed in this era of enlightened geriatrics that the older patients with Colles' fractures obtain the best results if the fracture is more or less neglected and early physical therapy instituted. This attitude is not shared by the author as it is thought that the old patients deserve the same chance for as good a functional and cosmetic result as the younger patients. There was no patient of advanced years in this series in whom it was re-

gretted that malunion was prevented because the final result is judged better than the result that could possibly have been obtained if the fracture had not received optimum treatment.

SUMMARY AND CONCLUSIONS

1. Comminution of varying degree in Colles' fractures is much more common than generally recognized and is a very frequent cause of malunion. However, malunion in such cases is not inevitable and can be prevented.

2. Although reduction of this type of fracture is not difficult, malposition often promptly returns when the usual methods of immobilization are used.

3. The reduction of comminuted Colles' fractures can be maintained by Bohler's method of incorporating two transfixion wires in a plaster cast. It is recommended that this form of treatment be used more widely not only in the fracture with severe comminution but also in many of the unstable fractures with mild comminution.

4. To prevent redisplacement at least eight weeks of immobilization are necessary because solid union of the multiple fragments occurs slowly.

5. The value of repeated, complete active motions of the fingers and shoulder from the start of treatment and of the immobilized joints as early as possible can not be overemphasized.

6. Thirty-one patients with thirty-two comminuted Colles' fractures treated by the Bohler technic have been reviewed. Good or excellent results were obtained in 76 per cent of the patients followed up for a sufficient time; there were no poor results and no malunions.

7. The optimum treatment of Colles' fracture should not be withheld from any patient because of age alone. Elderly patients in this series responded well to the treatment described.

8. It is thought that the problem of malunion of the Colles' fracture can be solved if sufficient interest in this fracture can be aroused.

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ARTHRODESIS OF THE WRIST JOINT

GRAFT FROM INNER TABLE OF THE ILIUM

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ARTHRODESIS is a very valuable procedure in a variety of disorders of the wrist. A limb with no other disability than this gives surprisingly good function and this can be promised when the pre-existing condition does not interfere with finger movements or rotation of the forearm.

This is a report of an unselected series of forty-nine consecutive arthrodeses of the wrist. Twenty-seven of these were personal cases and twenty-two were done by seven colleagues, using essentially the same method. The method, as illustrated in Figure 1, was evolved during the war years with the R. A. F. Orthopaedic Service and, since then, at the Queen Mary Veterans Hospital and the Royal Victoria Hospital in Montreal covering a period of eight years. During that time a large number of traumatic conditions of the wrist joint have been seen and a small number of a variety of other conditions.

Most methods for arthrodesis of the wrist described in the literature have been given a previous trial. Any adequate excision of hyaline cartilage with immobilization completely enough and long enough, with or without the use of a graft, will produce a stiff wrist. The most satisfactory arthrodeses, however, appear to be those which have the most extensive fusion, namely, radiocarpal, mid-carpal and carpal metacarpal joints.

It is sometimes claimed that partial fusions are best. In our experience they are often painful and interfere with function of the limb. We cannot see the use of a few degrees of carpal metacarpal movement which may be painful and is rarely under muscle control. The callus of a partial arthrodesis cannot consistently be restricted to a particular joint compartment but it is essential to preserve the first carpometacarpal joint and preferable to preserve the fifth when there is no arthritic involvement. Our method should, therefore, give as complete a fusion in the shortest period of time as is consistent with function if it is to be the optimum procedure. This method in practice, as shown by the follow-up, often does achieve this aim. It is our clinical impression that it is more often successful than the other methods commonly used. The procedure has been used long enough to enable us to report both the advantages and

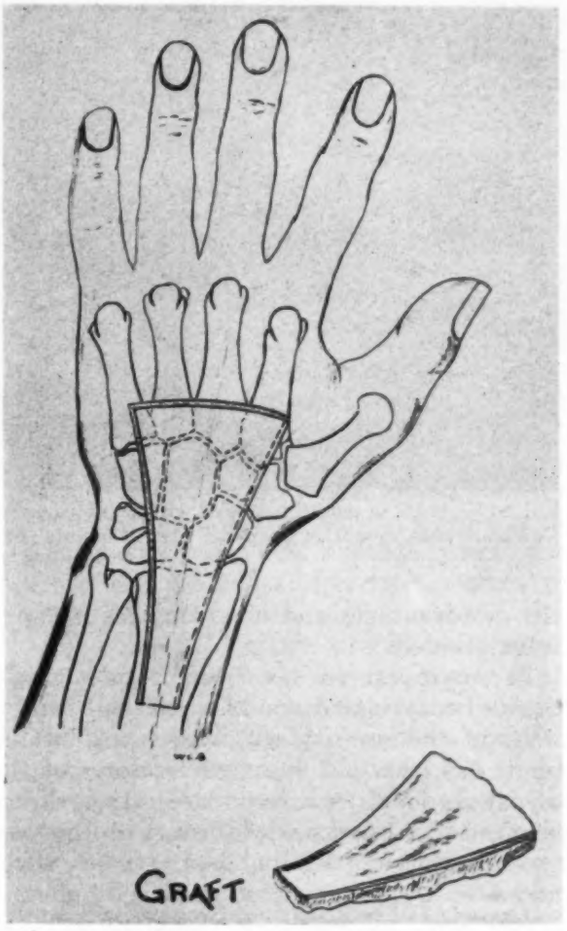

FIG. 1. Arthrodesis of wrist; indications are old ununited fracture scaphoid with advanced arthritis, osteo-arthritis including degenerative arthritis due to trauma, infective arthritis, tuberculous arthritis, rheumatoid arthritis; paralysis, infantile-spastic-traumatic, and congenital deformities. Technic used is as follows: use pneumatic tourniquet; cut deep bed in carpus, lower end of radius and second to fifth metacarpals; graft from inner table ilium cut in a fan-shape to fit; and immobilize until x-ray evidence union which is usually four months; graft from inner table of ilium with natural curve and cortical surface for dorsal aspect and cancellous surface for graft bed.

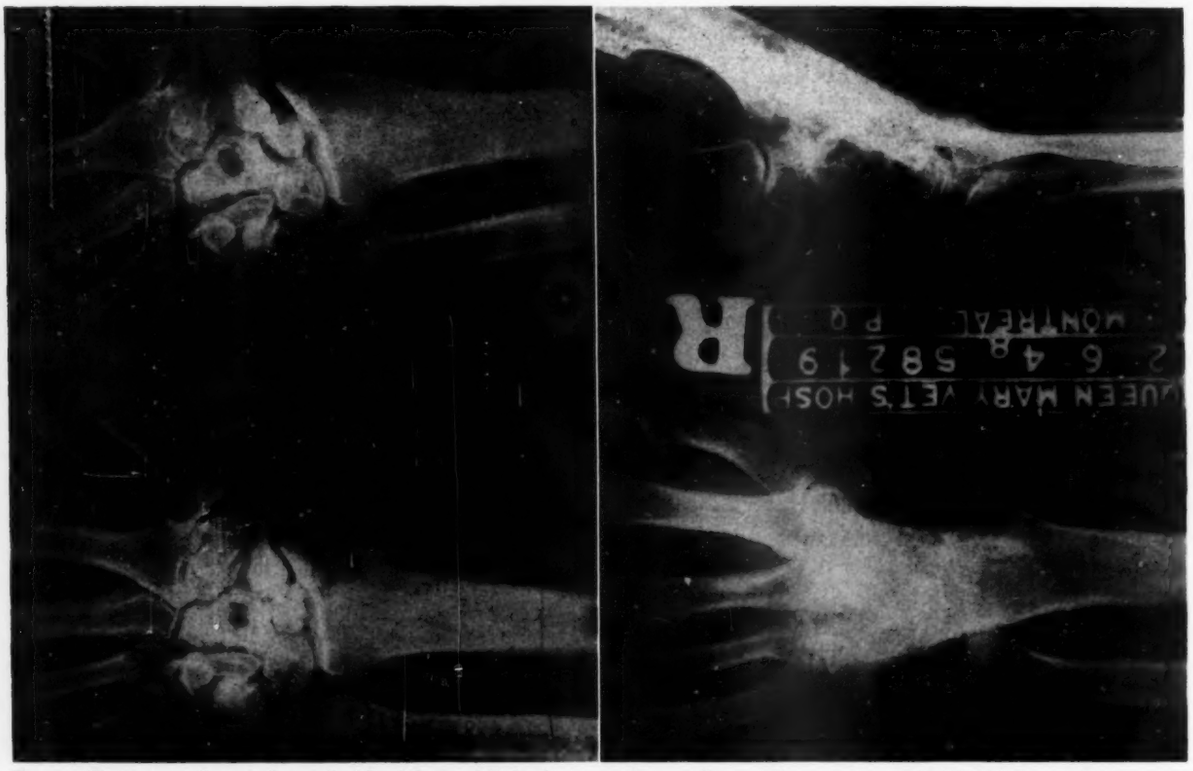

FIG. 2. Fracture of carpal scaphoid with established non-union and secondary osteo-arthritis. Note multiple cysts which are also present in the other wrist. Possibly this is Jungling's disease with a pathologic fracture.

the disadvantages and how complications are to be avoided.

In our experience the most common single cause (twenty-one cases) of a stiff and painful wrist of the severity requiring fusion of the joint, has been old ununited fractures of the carpal scaphoid with secondary osteoarthritic changes. The usual story is history of injury to the wrist (with or without x-ray studies) diagnosed as a sprain and untreated. Symptoms persist until eventually it is recognized that there is an old fracture of the carpal scaphoid, with established non-union and fully developed osteoarthritis, with continuing degeneration in the function of the wrist. (Fig. 2.) Approximately 90 per cent of these are relieved by various procedures and are able to tolerate their disability. The others which do not get alleviation of symptoms are fused. They have passed the stage in which curing the non-union of the scaphoid by bone grafting has any effect on the pain and stiffness of the wrist joint.

Arthroplasty of the wrist joint in these cases by excising the proximal row of the carpus rarely gives a satisfactory result. There is usually painful limitation of movement, a good deal of weakness and progressive degeneration due to traumatic arthritis. (Fig. 3.)

It appears that osteo-arthritis affecting one portion of the wrist joint, for instance, the radiocarpal compartment, will spread until it involves the mid-carpal and carpal metacarpals; for this reason arthrodesis is necessary. The best function of the limb is achieved when the wrist is a solid block of bone; pain is abolished and the limb used. Until we learn to do a sensory denervation without producing neurotrophic changes, arthrodesis will be the best procedure for severely damaged wrists.

In any fracture involving the carpal bones, including the lower end of the radius and the bases of the metacarpals, if there is not a hair-line reduction and a minimum of joint involvement due to callus, traumatic arthritis may arise which in the more severe cases requires arthrodesis. Accurate reduction and relatively early active movement should keep these to a minimum. Malunions due to improper fracture treatent are still too commonly seen (Fig. 3.)

In infective arthritis we may find that the infection thoroughly ankyloses the joint; and if it has been splinted in good position, a satis-

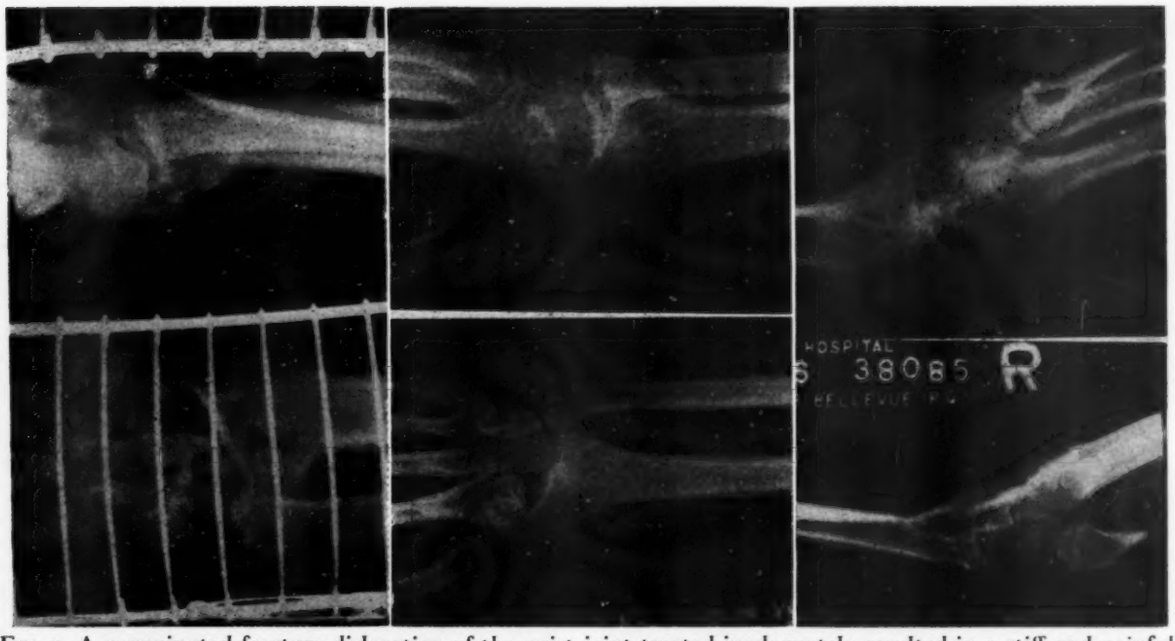

FIG. 3. A comminuted fracture dislocation of the wrist joint treated inadequately resulted in a stiff and painful wrist; arthroplasty done elsewhere did not improve matters. Good function was restored to the limb by excision of the lower end of the ulna and fusion of the wrist.

factory end result is obtained. Very commonly, however, the ankylosis is incomplete; residual movement is painful and because of this there is marked disuse atrophy and gross interference with the function of the limb. Furthermore, the small range of movement present predisposes to flares of the old infection. More often than not, these cases of painful partial ankylosis are in a position of deformity. For all of these, excluding other contraindications and under antibiotic control, arthrodesis gives a very satisfactory answer.

In tuberculous arthritis there are many factors to consider. It is a local manifestation of a systematic disease and it is most important that all available local and general measures are taken to build up resistance to the disease. When the patient shows good resistance, as indicated by gain in weight, general well-being, normal sedimentation rate and a normal hemogram, arthrodesis should be considered. If a discharging sinus were present, it should first be cleared up by both local and systemic use of streptomycin or aureomycin. Provided there is a healing reaction as indicated by some recalcification in the region of the disease, it is not necessary to delay the operation further. (Fig. 4.) Liebolt reports that of twenty-five tuberculous wrists treated conservatively, none were cured; of twenty treated by his method of fusion, 60 per cent were cured. We have only three cases of tuberculous wrist to report but they all show satisfactory arthrodesis and cure.

Rheumatoid arthritis usually shows a deformity which requires a wedge resection as part of the procedure in order to obtain the optimum position.

The chief value of the procedure in spastic paralysis is to improve the appearance of the hand and the function of the limb in that the fused joint is easier to handle than a curled-up spastic one.

In infantile paralysis it is often an invaluable procedure as part of the reconstructive program giving stability and allowing better function of tendon transferences.

The operation is carried out using a pneumatic tourniquet and Lane's "no touch" technic. The incision 4 inches in length is centered over Lister's tubercle. The extensor retinaculum is carefully dissected back so that its subsequent repair is easy. The common extensors are retracted to the ulnar side, extensor pollicis longus is released from Lister's tubercle and subperiosteal and subcapsular sharp dissection is done, exposing the lower 1½ inches of the radius, all the carpal bones and the bases of the second to fourth or fifth metacarpals. In doing this the extensor carpi radialis is, of course, peeled off with its capsular and bony attachment. A fan-shaped bed is then outlined with a motor saw and completed with

4A

4B

FIG. 4. A and B, tuberculosis of the wrist joint, immobilized postoperatively in plaster fourteen months; patient was under sanatorium treatment for this and pulmonary disease. Arthrodesis is sound and the lesion has remained healed.

the cutting burr, then deepened with curved osteotomes. The proximal and distal margins are undercut deeply and the entire bed is deepened a full ½ inch or more. A pattern of this bed is then made using silence cloth and from this an iliac graft is cut to fit. The graft is then pressed into position with traction on the wrist. Dorsiflexion into the optimum position is done, firmly impacting the graft. The capsule and periosteum are easily closed if the graft has been deeply enough inlaid; this is necessary to leave a smooth gliding surface for the tendons. It is not essential to reconstruct Lister's tubercle but the extensor retinaculum must be carefully repaired.

The iliac graft is taken by using a 4-inch incision extending along the crest of the ilium from the anterosuperior spine. A subperiosteal exposure of its inner surface is then done. With the use of deep abdominal retractors, the inclination of the inner surface of the ilium can be seen. Using numerous thin osteotomes, a graft is taken as thick as possible in order to leave an intact outer cortical surface. The deep portion of the graft is best separated with curved osteotomes. An alternative donor site occasionally used has been the curved outer surface of the ilium just anterior to the posterosuperior spine. These two regions give a curved graft with a concave cortical surface and a convex cancellous surface which fulfills the requirements. This type of graft unites more readily than a tibial graft and more certainly than either iliac chips or an osteoperiosteal graft.

The optimum position for arthrodesis varies between 20 and 25 degrees of dorsiflexion, with the third metacarpal and radial shaft in the neutral position. Position during fitting of the graft and also molding of the plaster is an important thing. There are four points to watch out for in positioning the hand, all of which are covered if one considers the position of the closed fist resting on the flat surface: (1) the degree of dorsiflexion; (2) the third metacarpal and radial alignment; (3) rotation of the hand to the radius and (4) the formation of a metacarpal arch.

The inferior radio-ulnar joint is usually a separate joint compartment from the carpal joints and this is, of course, not encroached upon. If, however, there is damage to this joint as an associated injury, it is best dealt with by excision of the lower end of the ulna. (Fig. 3.)

This produces a satisfactory result, if the pronator quadratus is not damaged, and full power will be preserved. If there has been a gross forearm injury with damage to the interosseous membrane and the superior radio-ulnar joint, excision of the lower end of the ulna is inadvisable, as instability and symptoms due to this will persist. In such a case possibly arthroplasty of the inferior radio-ulnar joint should be carried out as a separate, later procedure. Excision of the lower end of the ulna is only an innocuous procedure if these conditions are met.

If arthrodesis is indicated in young people, the radial epiphysis must be preserved; if it is already damaged by injury or disease, it must be completely fused in order to prevent subsequent deformity.

The first carpometacarpal joint is always preserved; if it were involved in the original disease or injury, we would prefer to do an arthroplasty at a later stage if possible.

When there is both damage to the inferior radio-ulnar joint and the necessity of doing a tendon transference, the ulnar approach has been used as described by Smith-Petersen (a deep slot is cut through the carpus curved to take this iliac graft). This has the advantage of keeping dorsal scarring, which might interfere with the tendon transference, to a minimum.

The routine postoperative procedure is to apply a full arm plaster cast extending from the distal palmar crease and the proximal I.P. joint of the thumb. This is split in its entire length to allow for the postoperative reaction. If we neglect the arch in our foot casts we produce flat, painful feet. It is not so well recognized that the same error in hand casts produces an appreciable loss of the power to grasp. The limb is elevated and if reaction is at all marked, circulation is improved by doing a sympathetic block. About the twenty-first day the cast and stitches are removed. This should be done carefully in order not to strain the graft or lose the position of dorsiflexion. A light forearm cast is then applied and molded well into the concavity of the radius in order to control rotation. This is then reinforced by airelite and should be retained for about three months. Airelite by itself does not mold well and it would be necessary to carry the cast around the elbow to control rotation if this were used alone. It is a very valuable reinforcing material, however, and eliminates the danger of non-unions due to cast breaks or refracture of the graft.

At about three to four months we reach a stage called "firm union" when it is safe to remove the cast and use the hand lightly. There is an intermediate stage at about four to five months called "sound union" when light work is permissible (lifting up to about 10 pounds). There is a final stage at about nine months called "consolidation of union" when heavy work can be done. These stages are determined by characteristic x-ray findings and not the lapse of time.

In dealing with a tuberculous wrist or an uncooperative patient with any condition we should continue our external fixation until we have "consolidation of union." It is not necessary in the others but it is better to err on the side of excessive protection.

Forty-nine arthrodeses have been done up to April, 1949, for the following conditions: fractures of carpal scaphoid with osteo-arthritis, twenty-one; compound fracture dislocation of wrist, nine; nerve lesions with wrist drop, six; fracture dislocations of wrist, two; Keinbock's disease with secondary osteo-arthritis, three; tuberculous arthritis, three; fracture of semilunar, one; infective arthritis, one; osteochondritis dissecans with osteo-arthritis, one; rheumatoid arthritis with deformity, one; and Jüngling's disease, one.

The time for union (first operation) was as follows: united in three months, twenty-eight; four months, nine; five months, two (prolonged by poor fit of the graft); six months, one (tuberculous); twelve months, one (tuberculous); fourteen months, one (tuberculous); and sixteen months, one (prepenicillin days with a flare of old infection).

The time for union (second operation, four cases) was as follows: united in three months, one; incomplete, three. Two may be attributed to broken casts; two were due to starting heavy work too soon.

In regard to non-unions (two cases) one may be attributed to operative technical error; one was due to an infection with abscess at two and one-half months postoperatively. These did not have a second operation as the close fibrous union gave a good enough function for the patients to carry on with their work.

The end results (anatomic, functional and symptomatic) were as follows: excellent twenty-

five, good fourteen, fair four and incomplete six.

COMMENT

Analysis shows no one surgeon had more than two significant complications regardless of the number of arthrodeses done. The complications reported are all avoidable. The incidence is lower than most reported series but is not as good as one. Good results depend on careful operative technic, postoperative care and follow-up, and these results improve with experience.

Acknowledgments. We wish to express our appreciation to Sir Reginald Watson-Jones, Air Commodore H. Osmond Clarke, S/L E. W. Somerville and Drs. J. G. Shannon, A. L. Walker, W. G. Breckenridge, C. E. Lamoureux, J. M. McIntyre, Gavin Miller and J. G. Petrie.

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ADULT INJURIES OF THE RADIAL HEAD AND NECK*

IMPORTANCE OF TIME ELEMENT IN TREATMENT

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THIS report comprises a review of all adult radial head and neck injuries treated on the Fracture Service of the Presbyterian Hospital from 1938 to 1947. A total of 261 such injuries have been studied of which 113 are sufficiently documented to form the basis of this report. These fractures are classified in three groups according to their pathologic condition. Epiphyseal injuries are omitted and will be reported separately.

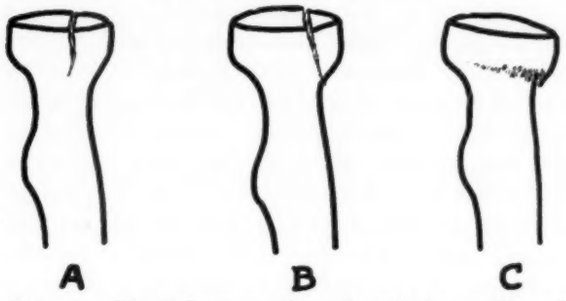

FIG. 1. A, linear fracture through articular surface of radial head; B, chisel-type fracture; C, fracture through neck with slight tilt of head.

GROUP I

Group I, consisting of seventy-nine patients, includes undisplaced fractures of the radial head. Most of them show x-ray evidence of a linear vertical fracture through some part of the articular surface of the radial head. (Fig. 1A.) In some there is a chisel-type fracture extending from the articular plateau through the cortex of the neck (Fig. 1B) and in others the cortex of the radial neck is buckled with a slight tilt of the head. (Fig. 1C.)

These fractures *per se* require no treatment. The joint capsule becomes distended with blood which causes gradually intensified pain and limitation of motion. Treatment is directed toward tense hemarthrosis. Aspiration of the elbow joint removes encapsulated blood, relieves pain and improves motion at once. A sling or splint for twenty-four hours discourages fresh bleeding and recurrence of intracapsular tension. Active motion within pain limits is begun the next day. The use of a sling or splint for two weeks or longer as advocated by some authors has prolonged disability out of all proportion to the severity of the injury.

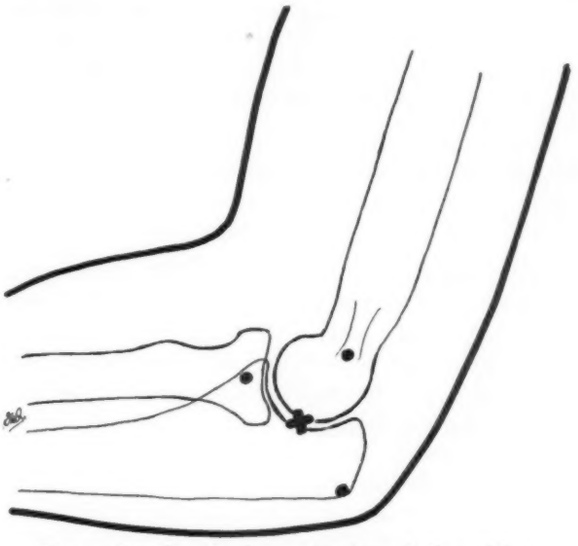

FIG. 2. Landmarks for aspiration of elbow joint.

Aspiration is performed from the lateral side of the elbow using a point of entry centered between three bony landmarks, the lateral epicondyle, the radial head and the tip of the olecranon process. (Fig. 2.) This must be performed with strict sterile technic. The skin is shaved and cleansed and the operator's hands scrubbed and gloved as for major operations.

Patients treated by this method enjoyed the greatest symptomatic relief and the earliest return of function. Fifty-nine per cent of undisplaced fractures were treated by aspiration. Seventy-six per cent of these gained full motion in thirty days. Of the remaining non-aspirated patients only 44 per cent gained full motion in an equal length of time. Those

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patients with limited motion at the time of clinic discharge gained full motion in three to six months regardless of type of treatment. The average length of follow-up was one year and eight months. Final rating was 4–4–4 for 75 per cent and 4–3–4 for 25 per cent

SUMMARY OF GROUP I
TOTAL CASES TREATED 212 OR 81 PER CENT OF ALL INJURIES OF WHICH SEVENTY-NINE ARE ADEQUATE TO REPORT

Group I	Aspirated	Non-aspirated
Total 79 cases	47 cases	32 cases
Full motion in 30 days	76%	44%
Average clinic Rx all cases	30 days	
Average follow-up all cases	1 yr. 8 mo.	
Final rating all cases	4-4-4 for 75%; 4-3-4 for 25%*	

*4–3–4—(3) Occasional slight pain with use and bad weather ache.

Final rating denotes A—S—E. A represents anatomy, S, joint motion and symptoms and E, economic rehabilitation; 4 equals 100 per cent; 3 equals 99 per cent to 76 per cent, etc.

of all patients in this group. The 25 per cent were marked down only for slight occasional pain with use and occasional bad weather ache. Anatomy and function were perfect in every patient. Results of Group I cases are summarized in Table I.

GROUP II

Group II, consisting of twenty-three patients, includes displaced fractures of the radial head with an intact joint capsule as demonstrated by clinical signs of hemarthrosis. All fractures in this group were treated by complete excision of the radial head through a lateral operative approach. Recognition is given to those few fractures in which fragments may pierce the joint capsule laterally or posteriorly. None was encountered in this series but they belong to this group and should be treated similarly. Fractures in this group include complete avulsion and rotation of the radial head, fracture of a sector of the head with depression and separation, fracture of the neck with tilt of the head or gross comminution. The mechanism of fracture is a fall on the outstretched hand with impingement of the radial head against the capitulum. The cartilage of the capitulum was lacerated or fibrillated in 30 per cent, but fracture of the capitulum was not encountered.

Whether or not to remove the head is a matter of judgment. Experience has proved beyond question that far better results are achieved if all displaced fractures of the radial head are treated by excision of the entire head followed by early active motion, rather than by attempted closed reductions that seldom succeed and prolong immobilization. If degree of displacement does not justify active motion within twenty-four hours, the radial head should be removed.

Operation is performed through a lateral incision over the radial head just posterior to the common extensor tendon which provides a practically bloodless field. The dorsal interosseous nerve two fingerbreadths below the radial head is respected both by incision and retraction. Removal of fragments alone or partial removal of the head has been abandoned as entirely unsatisfactory. Clean excision of the entire head through the neck with an osteotome proximal to the orbicular ligament and cauterization of the raw surface of the radial neck with the electrocautery, is the operation of choice. All patients in this group were so treated.

The decision to operate should be made at once and the operation performed immediately within the first twenty-four hours after injury. Active motion within pain limits is started the next day and the patient is instructed that the optimum period of recovery of function is during the first few weeks following operation and he is encouraged to gain all possible motion within this interval.

The argument has been advanced that excision of the head may result in shortening of the radius with disability at the lower radioulnar joint. This argument is tenable only in children. Neither by x-ray nor clinical measurement were there any instances of change in length of the radius or complaints of malfunction at the wrist in adults. The only observed departure from normal anatomy besides the absent radial head was a 5 degree lateral instability of the elbow in four patients.

The best results were achieved in those patients operated upon within twenty-four hours following injury. They required the shortest period of postoperative treatment and gained the earliest return of function. Those operated at four to seven days and one to six months required longer active treatment and were slower to regain function.

GROUP III

Group III, consisting of twelve patients, includes displaced fractures of the radial head associated with dislocations of both bones of the forearm at the elbow. This group of injuries differs from Group II in one essential detail. draw attention to this group of radial head fractures distinct from other displaced fractures of the radial head"? It is because this type of fracture, with its anterior extracapsular pathologic condition, pursues a course entirely different from the Group II fractures

SUMMARY OF GROUP II

TOTAL CASES TREATED 35 OR 14 PER CENT OF ALL INJURIES OF WHICH TWENTY-TWO ARE ADEQUATE TO REPORT

Group II	Op. under 24 hr.	Op. 4–7 days	Op. 1–6 mos.
Total 22 cases	15 cases	4 cases	3 cases
Days in hospital	7	4	5
Days in hospital and clinic	45	57	70
Motion at clinic discharge	50% had full motion	1 full motion	1 full motion
Full motion in remaining cases	All in 3–6 mo.	2 at 4 and 13 mo.‡	2 at 1½ yrs.
Regeneration of bone at excision site	None	3*	None
Average follow-up all cases	2 yr. 6 mo.		
Final rating all cases†	6 were 3-4-4; 15 were 3-3-4; 1 was 3-3-3‡		
Wrist changes	None		

* Three of the four patients operated upon four to seven days developed a regrowth of bone from the radial neck. None of the others did.

† A. 3—Absent radial head; four patients with 5 degree lateral instability of the elbow.
S. 3—Slight pain or weakness with use; bad weather ache.

‡ E. 3—One patient operated upon at one week was followed only six months and had some disability at work and 10 degrees limitation of full pronation and supination.

The dislocating force causes a laceration of the anterior capsule and brachialis muscle. The same force fractures the radial head against the capitulum and drives the radial head fragments anteriorly often through the capsular rent into the substance of the brachialis muscle. Associated fractures of the coronoid process are common. Nerve injuries may accompany dislocation.

Clinically, in addition to the physical signs of dislocation, there is anticubital swelling, tenderness and ecchymosis. These signs warn of torn capsule and indicate an extravasation of blood into the anterior extracapsular tissues. Laceration of the brachialis muscle contributes to this anterior swelling and ecchymosis. The lateral x-ray usually shows anterior displacement of the radial head fragments to a degree greater than an intact capsule would permit. Two patients presented the same physical signs without x-ray evidence of dislocation and at operation a laceration of the capsule and brachialis muscle was found. These reduced dislocations must be recognized clinically by their anterior soft part pathologic disorder. They belong in the Group III category and are treated similarly.

The question may now be asked, "Why just described. As a group these fractures are predisposed to myositis ossificans. This probably depends upon the combination of hematoma, lacerated muscle and the presence of displaced fragments of the radial head which provide a local source of calcium for new bone formation.

The treatment of these patients is based upon a follow-up study of similar cases treated on the Fracture Service during the years previous to this report, i.e., previous to 1938.[1] There were twenty patients with anterior extracapsular pathologic disorders. Ten of these were operated upon less than twelve hours following injury and none developed myositis ossificans. The remaining ten were operated upon two to four days following injury and five of these developed myositis ossificans (Fig. 3.) In other words 50 per cent of those patients operated upon after twenty-four hours developed this complication.

The operative approach is considered a factor of importance and one was chosen which would evacuate the hematoma and give ready access to the anterior joint. A transverse skin incision is made across the anticubital space. Vertical incisions form keloid scars which often contract. The interval between brachi-

3A 3B

FIG. 3. A, myositis ossificans twenty-four days following late operation; B, same 3 months following late operation.

oradialis and biceps muscles is separated and the radial nerve gently retracted with brachioradialis. The fibers of the underlying brachialis are separated exposing the anterior capsule and pathologic condition. The joint is further opened and the radial head and fragments dealt with as in Group II fractures. To insure against fluid tension in the wound area, the capsule and deep fascia are left open and only the skin closed. The transverse scar becomes almost imperceptible with healing.

Pursuing early operation, an average of six hours following injury, and employing the anterior approach on all twelve patients in this group, there was not a single instance of myositis ossificans, a total of twenty-two patients operated upon under twenty-four hours that avoided this complication. The results are summarized in Table III.

The Group III fractures, because they were more severe and were complicated by dislocation, other fractures and nerve injuries, required a longer period of treatment and were slower to regain function. The high incidence of regeneration of bone at the site of excision, 50 per cent of twelve patients, may be a residual manifestation of the tendency to form new bone in this type of injury. It is interesting to observe in successive x-rays taken over a period of years that new bone formation about the radial neck reaches a peak in amount and then gradually begins to recede. This shows the same pattern of increase, plateau and decline observed in myositis ossificans. All six patients show a minimal residual amount of excess bone about the radial neck on last examination.

SUMMARY OF GROUP III

TOTAL OF FOURTEEN CASES, 5 PER CENT OF ALL INJURIES, OF WHICH TWELVE CASES ARE ADEQUATE TO REPORT

Dislocation on admission	10 cases—5 with coronoid fractures
Dislocation suspected and torn capsule and brachialis found at operation	2 cases
Associated injuries	1 compound; 2 ulna nerve palsies; 1 radial nerve palsy
Average time injury to operation	6 hours (1½ to 16)
Average hospital days	15 days (7 to 18)
Average hospital plus clinic days	102 days (62 to 174)
Motion begun	6 days (2 to 23)
Full motion gained	5 cases in 6 to 14 mo.
Average motion in remaining 7 cases	45/170 P & S full except one with S-35 degrees
Average follow-up	3 years
Final rating	All (3)-3-4*
Myositis ossificans	None in 22 cases operated early
Regeneration of bone at excision site	6 out of 12 (50%)
Wrist changes	None

* (3) Absent radial head; 2 cases had increased carrying angle.

3 (1) Limitation of motion; full extension minus 10 degrees and full flexion minus 10 degrees in 7 cases (2) bad weather ache;(3) slight pain with use; (4) crepitation with rotation.

SUMMARY

A total of 261 injuries to the radial head and neck in adults have been reviewed of

which 113 are sufficiently documented to report. All patients presented have been followed a minimum of six months and an average of two years, six months. Three groups are classified according to their essential pathologic condition. Group I comprises 81 per cent, Group II, 14 per cent and Group III, 5 per cent of total injuries reported.

Group I injuries with fracture undisplaced and hemarthrosis the outstanding pathologic disorder are best treated by aspiration of the elbow joint and active motion within pain limits in twenty-four hours.

Group II injuries with fracture displaced and joint capsule intact are best treated by early excision of the *entire* head and early active motion.

Group III injuries with fracture displaced and joint capsule torn anteriorly by an associated dislocation at the elbow require immediate action. Fifty per cent of such patients operated upon later than twenty-four hours following injury through a lateral operative approach developed myositis ossificans. All patients in this series were operated upon an average of six hours after injury through an anterior approach; all avoided this complication.

Statistical summaries of total cases reported substantiate these views.

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COMPLICATIONS ARISING IN THE TREATMENT OF FEMORAL SHAFT FRACTURES

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MUCH has been written on the subject of femoral shaft fracture over the past few decades and some of the best known practitioners in the field of fracture surgery have expressed their views in the literature on the subject. Notwithstanding the fact that some of our ablest men with the most mature judgment have given treatment of this fracture their attention, there is a startling division of opinion as to the best method of treatment and marked discrepancies in end result studies of patients treated in similar fashion. Comparative statistical reports vary so greatly that the reader is forced to the opinion that no method is pre-eminently superior to another. The studies indicate the degree of skill exercised in alternative methods of treatment employed by supervising surgeons or surgical group making the report rather than giving a definite answer as to how the rest of us should treat fracture of the femoral shaft.

The very diversity of opinion tells us that this is a problem fracture with no universality of treatment to be prescribed and therefore perhaps profitable for occasional review even though no new thoughts may be expressed. It is our purpose to mention the more common complications arising from various standard methods of treatment and to cover in more detail the complications which occur in this fracture no matter how treated.

Probably the most venerable of modern methods of therapy is that of external fixation by means of a plaster cast. This of course implies a proper reduction followed by adequate and prolonged fixation in a double leg plaster spica. This was the course of treatment so ably followed by Willis Campbell[3] and Robert Jones.[9] Complications arise from this form of treatment as with all others. The general trend away from the use of the plaster spica is recognition of the fact that many complications arise from the prolonged rest of such a large portion of the body. These may be such things as the general retrogression of the physical status, mental deterioration, thrombophlebitis, renal calcinosis and development of pressure areas.

Complications may arise, however, in the plaster cast treatment of this particular fracture. A well reduced position may be lost during application of the cast. Finally there may be loss of alignment and even overriding after an originally adequate reduction and immobilization due to pull of heavy thigh muscles. It still remains a satisfactory form of treatment in the hands of those aware of its possibilities and liabilities.

Another way of handling this injury may be described as the pin and plaster method by which reduction and fixation is accomplished by placing pins in the shaft of the femur above and below the fracture site and after reduction has been accomplished to maintain the position by bolting the pins together or incorporating them in a plaster cuff. Such a method has been described by Moore[13] and advocated by Anderson[1] and others. Complications peculiar to this method of treatment consist of improper placement of pins with possibility of soft tissue damage, infection of pin sites, loosening of pins or bars or softening of the plaster cuff resulting in loss of an adequate position. We do not personally advocate its routine use but it does have an appeal for the occasional patient whose physical or mental status demands an ambulatory form of treatment.

Probably the most commonly used form of therapy for this fracture is traction. Most writers claim adhesive skin traction to be unsatisfactory although Kidner[10] claims good results with its use. Some men use Russell's traction for treating this injury.[5,15] The majority of men employ Kirschner wire skeletal traction and report good results when carefully supervised. There are advocates of both the transcondylar placement of the pin or wire and those who by choice prefer tibial tubercle placement. Our own preference is for the latter since we believe we can obtain better alignment

of short distal fragments and at the same time have no difficulty with the knee joint which could be blamed on the traction. Swart[20] advocates double wire traction for the longer distal fragments which are difficult to control.

Complications arising from the use of pins or wires may be listed as improper placement of the pin, breakage of pin and infection of pin site. It need hardly be pointed out that the joint itself is to be avoided and that placement of pins and wires is an operating room procedure. Complications arising from the use of traction are chiefly two. One arises from the use of too little weight in the first few days of treatment when traction is used as a means of reducing the fracture. It is our practice to anesthetize the patient and manually reduce the fracture if this has not been accomplished by traction in twenty-four to forty-eight hours. The second complication occurs after a few days of treatment from the use of too much weight when traction is used as a means of maintaining reduction. The great thigh muscles gradually lose their tonus permitting distraction of the fragments.

A fourth method of treatment used for femoral shaft fracture is reduction by operation and internal skeletal fixation followed by external protection for a period of time by casting or traction. There are few reports in the literature from writers advocating open reduction as the primary method of choice. Sherman[16] was a great believer in operative fixation but stated that at that time there were perhaps a dozen hospitals in the United States in which this could be safely done by routine. The late Clay Ray Murray[14] read a paper advocating this method of treatment but qualified his advocacy with a number of "if's" so that the average surgeon would hesitate to follow this dictum in the average hospital.

More typical perhaps is the attitude of Funsten and Lee[7] that operative fixation should be an unavoidable necessity rather than a treatment of choice. There is, however, a latitude of opinion as to what constitutes necessity. This revolves around the question of what is a satisfactory alignment and when one should intervene in a delayed union. These two controversial subjects are not easily resolved by precise definition but must be individually answered out of experience of the surgeon handling this type of problem. All agree that suspected soft tissue interposition requires operative reduction. Some writers show that the percentage of patients having complications is greater in the operative group and that the possibility of complications is greater than in those treated by closed methods. Complications we have seen include sepsis, breakage of plates, loosening and breakage of screws, improperly placed incisions and inadequate protection following operations. Thrombophlebitis and pseudarthrosis are likewise reported. Some statistics claim to show delay in union as a result of operation.

This hastily reviews the usually accepted methods of treating this fracture together with a listing of complications peculiar to the method of treatment. Four complications common to this fracture will be considered more fully.

Behavior Problems. While not ordinarily considered as a complication in the treatment of this fracture, it is our experience that this factor all too frequently interferes with the successful conclusion of a planned method of therapy and is responsible for prolonging the end result as well as contributing to a poor result. We have seen no statistical evidence presented in any series of case reports attempting to evaluate this factor and its influence upon the time of healing and on the final function. Many authors make comment that in a certain patient in their series a bad result was obtained because of lack of cooperation or interference in the course of treatment on the part of the patient.

We have noted emotional misbehavior fairly often in this group of individuals. It may take a mild form such as the anxiety state or emotional lability down to loss of interest in food and surroundings, uncooperativeness and even truculence. A true psychosis is not infrequently seen while mental aberrations among older age groups is not uncommon. Most of us can remember days when fracture of the femoral neck and trochanter was treated by prolonged casting. There were always a few older women going slowly mad until the disturbance they created necessitated the removal of the plaster spica.

It is our impression that these mental problems are seen more frequently in the casted patient but they are encountered whatever the form of treatment. We think it may be useful to assess the patient's mental and emotional status before embarking on any plan of therapy in an effort to make the adjustment before rather than in the midst of a committed course. This is not always possible for most of these

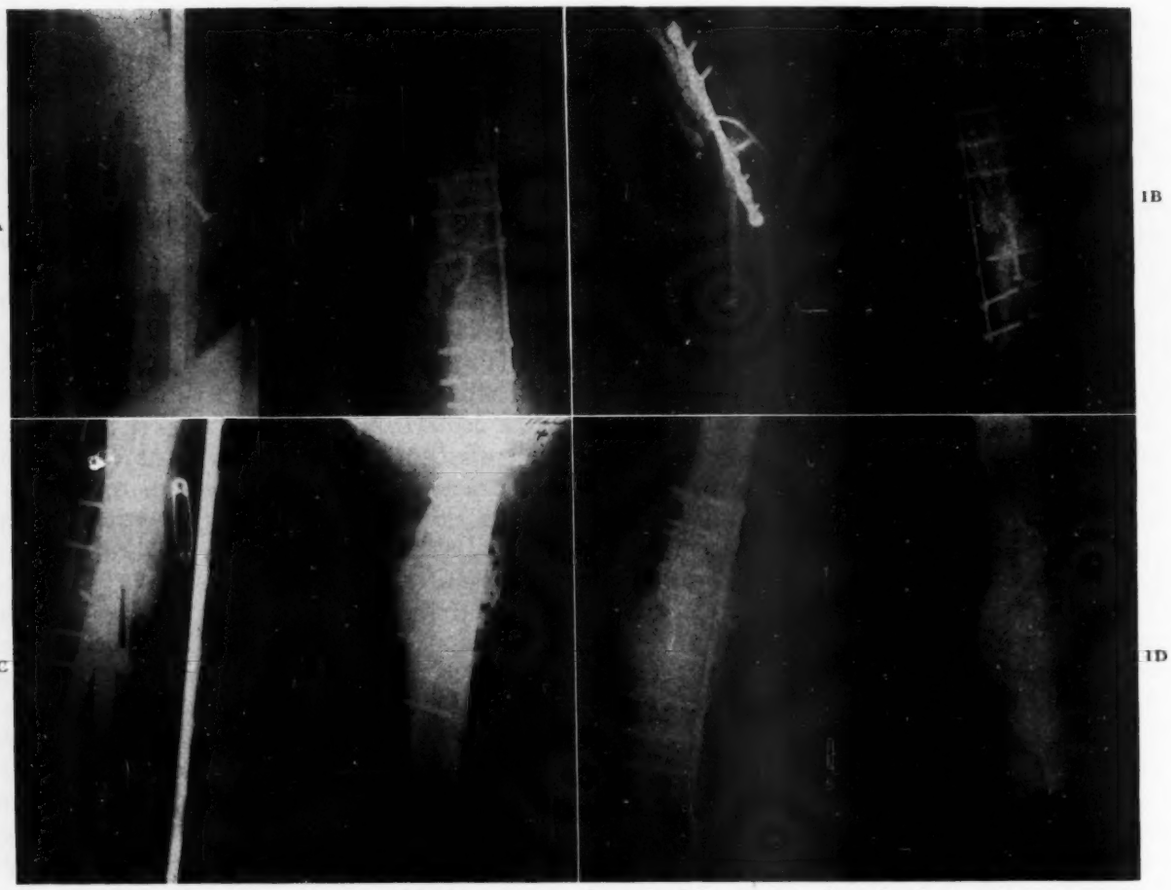


FIG. 1. Patient was a forty-five year old white steel worker who fell 45 feet and received pin-point compound fracture of femur with dislocated shoulder treated at first by traction. A, shows position at first operation six months after injury; B, appearance four months later after a fall in the harbor; C, reoperation, replating and tibial onlay graft; D, four months after reoperation.

individuals get into difficulties only after weeks of treatment. For this we have nothing better to offer than psychotherapy and a change of treatment if advisable. Under these circumstances one anticipates a poor end result.

We include x-ray pictures of one such patient who was previously treated by skeletal traction but who was uncooperative so that the fracture was overriding and unreduced. The fracture was then openly reduced and fixed with a plate and multiple chip grafts laid around the fracture site. After many weeks the patient was so abusive and difficult to handle that hospital authorities would no longer keep him and he was discharged with an ischial weight-bearing brace. One night a few weeks later he was pulled out of Boston Harbor as the culmination of a celebration with some friends. As a result of this episode the plate was bent, screws loosened and angulation of the fracture site occurred. (Figs. 1A to D.)

Refracture. That fractures of the femoral shaft show a tendency to refracture has been remarked upon by several writers. This is particularly true in the series of war wounds reported by Stuck and Grebe[19] and by Brav and Fitts.[2] These are, however, a specialized group of patients, many with compounded injuries actually or potentially infected, on whom the early treatment was dictated by meager facilities at hand and by the necessity for early transference from one hospital to another.

Even in reports of simple fractures found in civilian practice the incidence of what is called refracture is high enough to be disturbing so that McMurray[12] raised the question as to whether or not these fractures of the femora were taking longer to heal now than formerly. Watson-Jones and Coltart[23] replied that there was no difference in the healing time of this fracture but that nowadays there is a better

2A 2B 2C

FIG. 2. A, view of femur five months after plating and three weeks after removal of plate at another hospital; B, femoral shaft plated and tibial onlay graft in place; C, seven months after plating and grafting.

roentgenologic checkup of patients so that our criteria of healing is more exacting. Textbooks in general have been guilty of minimizing the healing time for this fracture. The same authors report the incidence of refracture commonly in the eighth to tenth weeks. Soto-Hall and Horwitz[17] report the average time of refracture in their series to be seven and a half months from the time of injury. Eliason and North[6] report refracture in five patients in their series, the time element ranging between four and sixteen weeks from the time of injury.

To our mind the word refracture implies a fresh fracture at a site which has already healed or in which the healing process is about completed in the repair of a previous fracture. If this is generally true, the word refracture is a poor choice to describe this condition. It is obvious from the literature that most authors contend the bone has never healed from its original fracture and that this entity is a loss of position in a bone which has not yet healed. It is an inescapable conclusion that refracture is associated with poor judgment as to the healing time of this fracture. Most writers say that this occurs in three to four months. This is the exception, however, and not the rule particularly if we keep in mind the time of refracture in patients with refracture reported by Soto-Hall and Horwitz.[17] We agree with McKeever[11] that criteria for satisfactory healing is obliteration of the fracture line with re-establishment of bony trabeculation.

Figures 2A to C are illustrative of refracture in a thirty-nine year old woman injured while skiing. The femur was plated and the plate removed five months later. We first saw her three weeks after this with a refracture which we treated by replating and bone grafting.

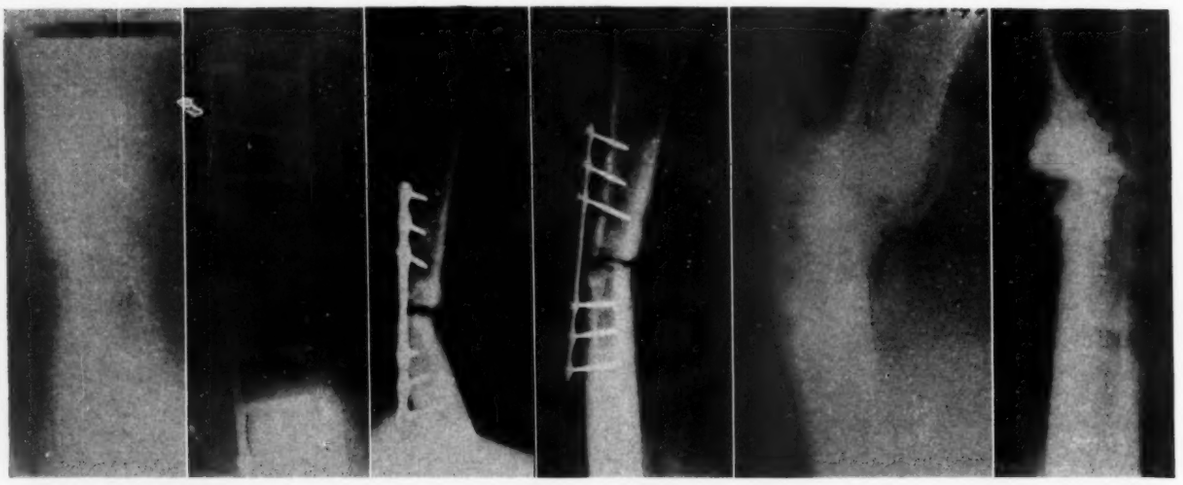
Knee Stiffness. Another troublesome complication of femoral shaft fracture is stiffness of the knee. This is reported following all forms of treatment and represents a real challenge to the surgeon.

McKeever[11] reports 82 per cent of his patients treated with traction could flex the knee to a right angle or better whereas only 59 per cent had this amount of motion following internal fixation while results were poorer still with external fixation.

VanGorder[22] reports stiffness of the knee in eleven out of forty-three adult patients followed, and the average arc of motion in these patients was 76 degrees.

Eliason and North[6] noted that six of their seventy-three patients had stiffness of the knee, how much is not recorded, and stated that all six of this group were treated with reduction and casting. One of these was a child. In a discussion of this paper Campbell,[3] an advocate of this form of treatment, said that his patients were not troubled with knee stiffness.

Stuck and Grebe[19] in their series in soldiers report that twelve or 10 per cent had motion of less than 90 degrees, a good record for the type of cases they were supervising, and attribute



3A 3B 3C

FIG. 3. A forty year old male run over by a truck was treated with Kirschner wire traction and spica; fracture was plated six weeks later; patient first seen by us one week after with temperature. A, postoperative plate; screws do not extend through both cortices; wound sepsis present; B, two and one-half months after plating; following this examination plate and screws were removed; C, view twelve months after injury; quadricepsplasty performed three years after injury.

the favorable results to the age group of patients they were treating together with early quadriceps exercises and early operation when indicated.

It will be concluded from the above reports that knee stiffness is a fairly common complication of this fracture but there is a wide diversity of opinion as to which method of treatment carries with it the greatest threat of subsequent fixation. Watson-Jones[23] states that immobilization of a normal joint or well placed traction through a normal joint is not responsible for subsequent stiffness but rather it is due to anchorage of the quadriceps apparatus by initial soft tissue injury or infection.

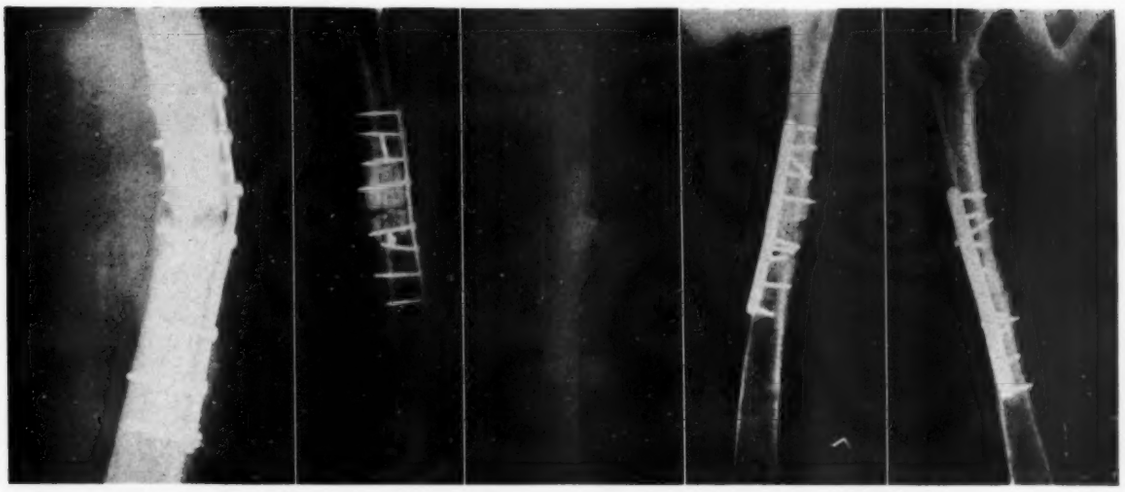
Charnley,[4] in an analysis of thirty-four patients reported, concludes that adhesions of the quadriceps is the greatest cause of stiffness and reports good results from quadricepsplasty.

Our own practice is to start quadriceps setting exercises early and to pursue active and passive knee exercises when healing of the fracture permits. This is continued for months if necessary so long as any improvement is noted.

In two patients has the Thompson[21] quadricepsplasty been performed. Figure 3 shows the fracture suffered by this patient. His arc of motion before operation was 5 degrees and after operation was 70 degrees. The second patient was Case 1 already reported. He had an arc of motion of 5 to 10 degrees before and 100 degrees after operation.

Delayed Union. It is admittedly difficult to define what should be considered a delay in healing time of this fracture. From what has already been quoted the normal healing time is reported variously by different authors. Furthermore the location of the fracture may influence the rate of repair. Funsten and Lee[7] state that fractures of the lower third tend to heal faster than fractures at other sites. One can only make a general statement that the average healing time is long at best. If we consider this to be five months, failure to heal somewhere in the five- to seven-month period may be considered delayed union.

There are of course time honored reasons for delay in union. Distraction of fragments from too much weight and angulation or overriding from ill-conceived traction are universally accepted. Other causes of slow union are found in delay in initiating treatment and failure to protect the limb until union is complete. An example of this factor can be seen in the x-rays of Case IV. (Figs. 4A to C.) She was a twenty-two year old girl with emotional instability treated initially in another hospital. The surgeon's note states that the reason for operation was lack of cooperation in Kirschner wire traction. Our first contact with her was six months after injury at which time the plate was broken and shaft angulated with melting of callus. She was re-plated and bone grafted finally obtaining a solid repair.



4A 4B 4C

FIG. 4. The patient was struck by an automobile and treated with skeletal traction. She was operated upon, plated and placed in a plaster spica. This was done in another hospital. A, view when first seen six months after injury with broken plate and melting of callus; B, reoperation with bone plating and tibial inlay graft; C, six months after reoperation. Case IV.

At the time of sustaining a fracture there are two common causes for delay in union: one is interference of the local blood supply, an assumption difficult to prove, and two is the interposition of soft parts. Most authors agree that the latter condition requires operation. Case V shows the x-rays (Figs. 5A to C) of a twenty-two year old clerk whose femur was fractured when struck by a steel beam. When first seen by us four months after his injury, there was a thin ribbon of callus on the medial surface with a well established gap between the bones which had been present since his admission x-ray. While traction may have been a contributing factor, it was suspected that there was a soft part interposition and we operated upon him. This was found at operation and the material was carefully curetted out trying to avoid the ribbon of callus already present. The gap was filled with bone chips and an inlay tibial graft laid down.

A point of disagreement appears to be the effect of open reduction on the healing time. Funsten and Lee[7] state that the outcome is improved and complications fewer with closed reduction. Soto-Hall and Horwitz[17] record no great difference in healing time between open operation with fixation and closed reduction. Ghormley and his group[8] reported operating in 32 per cent of their femoral shaft fractures and state that a slightly longer time is required for union in this group of patients. On the other hand Watson-Jones and Coltart[23] think that if open reduction is properly and carefully performed there is no contributing cause for delay in union. Infection of a compounded injury or infection introduced at time of operation is always a cause of delay in union.

Our own belief is that in the past when plating alone was done we could anticipate slow union in these fracture cases. As will be noted in some of the x-rays reviewed we have run the gamut of inlay grafts, onlay tibial grafts, iliac grafts and have recently used bank bone as a source material. Our preference at this time is for a massive onlay graft of tibial bone with the packing of bone chips all around this area with fixation accomplished by a bone plate. When this is properly performed, we have not noted delay in union.

In reviewing the opinion of authors over the years it is only fair to state that newer tools and technics may have modified their original opinions. Certainly the influence of some of the newer metals, use of antibiotics, intramedullary nail and the concept of the role of cancellous bone in producing faster repair are all measures which make an impact on this problem. However, we find ourselves in agreement with Kellogg Speed[8] that in spite of all the newer aids which come along an intelligent grasp of and energetic use of the fundamentals of fracture treatment will be found to make the greater contribution to the successful handling of this fracture.

5A 5B 5C

FIG. 5. A, shows fracture site four months after injury while being treated in skeletal traction; B, at operation the ribbon of callus was saved and fracture line crossed by tibial onlay graft and bone chips; C, view four months after grafting. Case V.

SUMMARY

1. Four of the usual methods of treatment of femoral shaft fracture are discussed as follows: (1) reduction with external plaster fixation; (2) pinning with external bar or plaster fixation; (3) traction and (4) operative internal skeletal fixation.

2. The more common complications which arise as a result of each method of treatment are mentioned.

3. Complications of this fracture common to all forms of treatment are discussed as follows: (1) behavior problems and their influence on end results; (2) refracture and its avoidance by adequate and prolonged protection; (3) knee stiffness, its incidence and control and (4) delayed union and its more common causes.

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MECHANICAL PROBLEMS IN OPEN REDUCTION OF FRACTURES

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MANY mistakes are made in the type of plate and screws used and in the method of application of these in the

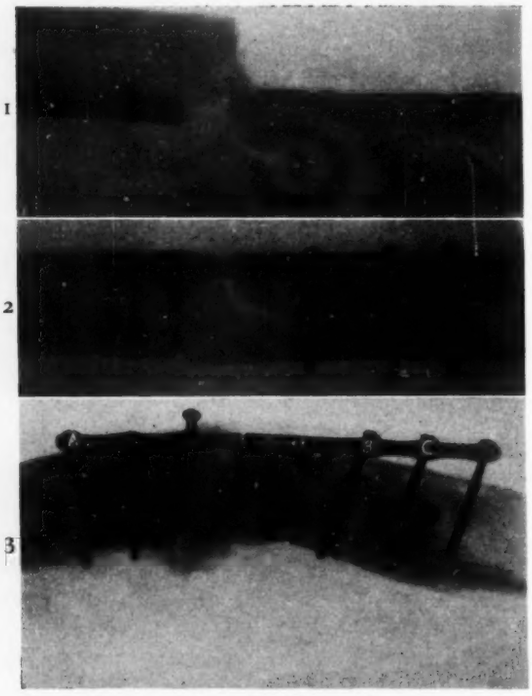
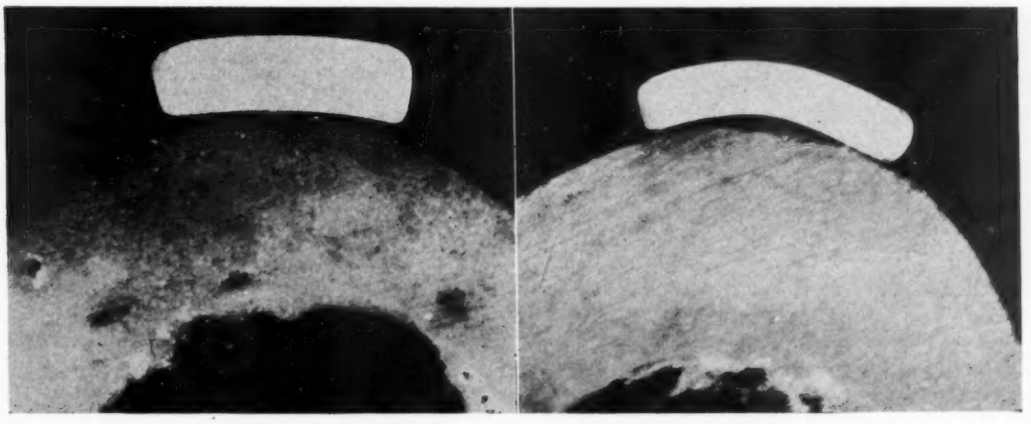


FIG. 1. Fracture of shaft of femur day of accident; in Russell traction.
FIG. 2. Fracture of femur after internal fixation.
FIG. 3. Four hundred thirteen days after internal fixation; screws A, B and C have broken; two others have pulled out. The plate at its distal end has separated from the bone. In later figures A is marked 1; B, 4; and C, 5.

fixation of fractures. For example the plate may be too short, improperly curved or marred before or during the operation. The screws may not be made of the same material as the plate and the flutes may be too long lessening holding power. The threads may be poorly cut or filled with metal filings. The screws may not pass readily through the holes in the plates. In application the drill may not be centered in the plate hole. The correct size of drill may not be used so that either there is lack of holding power if too large or excessive torque if too small which may result in placing excessive torsional stress on the screw at the junction of the head and shaft or may cause pressure necrosis within the screw hole. The screws may not be inserted perpendicularly to the axis of the bone. In a recent case because of the presence of screws which broke during the postoperative observation of a patient who had an open reduction done at Beekman-Downtown Hospital, we submitted the removed plate and screws to a metallurgist. A brief outline of the treatment of this patient is presented followed by remarks based on the metallurgic report giving reasons why internal fixation in this patient resulted in failure.

CASE REPORT

J. G., a forty-eight year old male, was admitted to Beekman-Downtown Hospital on July 25, 1946, suffering from the following injuries: fracture of left patella, fracture of middle third of shaft of left femur, fracture of mandible at symphysis, ascending ramus and condyle and concussion of brain. On admission he was placed in Russell traction (Fig. 1) with 10 pounds of weight preliminary to open reduction and internal fixation. This was delayed because of the poor general condition of the patient and concomitant injuries. On August 6, 1946, twelve days after admission, the patient was operated upon at which time a 5⅜ inch 18–8 SMo stainless steel six screw plate and three transfixion screws were inserted. (Fig. 2.) The patient was then placed in Russell traction with a 4-pound weight. The operative wound healed primarily. The postoperative course was uneventful. Quadriceps exercise was started fifty-five days postoperative, being delayed because of the fractured patella on the same side. X-ray film taken ninety-three days postoperatively showed some callus. At this time opinion was expressed by some of the staff that there was some bending of the plate. On December 4, 1946, 119 days postoperatively, traction was discontinued. There was no further bending of the plate and the screws were in good condition. On December 7, 1946, he was allowed to sit up in a chair. On December 23, 1946, he was fitted with a non-weight-bearing caliper, allowed up on crutches and discharged on December 24, 1946. He was



4A 4B

FIG. 4. A, section of improperly curved plate on section of human femur; B, section of properly curved plate on section of human femur.

followed periodically in the fracture clinic until September 29, 1947, when he was readmitted because of an ununited fracture and condition of screws and plate as revealed by x-ray. (Fig. 3.) On October 11, 1947 (fourteen months, six days after the operation), the plate and screws were removed and a new plate inserted in addition to iliac bone chips being placed around and between the fragments. He was placed in Russell traction until November 1, 1947, when a plaster body spica was applied. When seen last on May 10, 1949, he had union at the fracture site. He was walking without the aid of any appliances.

Why did screws B and C break in the middle of the medulla? According to the metallurgist there was no evidence of corrosion of either the plate or screws. Evidence of corrosion would certainly have been present if there had been any appreciable electrolytic action between them during the more than fourteen months that they remained in contact with each other exposed to the body fluids. Chemical composition and hardness must be the same or corrosion will take place. The plate and screws used on a patient should come at least from the same manufacturer if not from the same lot of steel. The chemical composition and hardness of the plate and screws were sufficiently alike to preclude electrolytic corrosion in this case.

The screw holes in the plate had been punched (not drilled) after the plate was curved so that they were fairly round. That has not been true of some other plates examined from the same manufacturer. Further, the screws were of sufficiently small diameter (0.1347 to 0.1355 inch) to pass freely through the holes in the plate. That also has not been true of some other plate and screw combinations examined from the same manufacturer.

The grossly insufficient curvature of the plate was the primary cause of the trouble. The transverse radius of curvature of the wide portions of this plate ranges from something over ¾ inch to something over 1 inch instead of the specified value of ⅜ inch. (Fig. 4A and B.) As a consequence the edges of the plate were not in contact with the bone and it offered no resistance to the forces tending to rock it. These were resisted only by the transverse stiffness of the screws which are not designed to carry such stresses. Other specimens of grossly insufficiently curved plates supplied by the same manufacturer have been removed because of fatigue failure of some of the screws. Such a plate should never be used but all the plates from army stock which this metallurgist examined were grossly deficient in this respect. It means that the plate is in contact with the bone along the line of the screws only and not at the margins.

At 175 days postoperatively all except the outermost layer of the proximal cortex under screw A (Fig. 3) was still dense. The bending stresses in the screw caused by rocking of the plate were thus concentrated close under the head where the fatigue failure occurred. At the time this x-ray was taken both the proximal and distal cortices around the last screw had lost much of their density so that this screw had already lost most of its holding power.

At 231 days the second screw distal to A had started to come out. B and C showed definite absorption in the proximal cortex

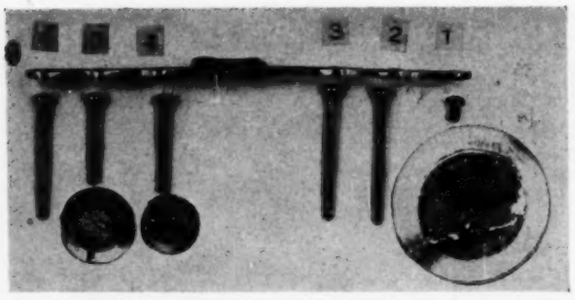


FIG. 5. Plate and screws with enlarged photographs of the broken ends of screws 1, 4 and 5. These show (most plainly in 1) the transverse markings characteristic of progressive failure under repeated excessive bending stresses caused by the plate rocking on the bone. The burring of the threads is shown on screw 3.

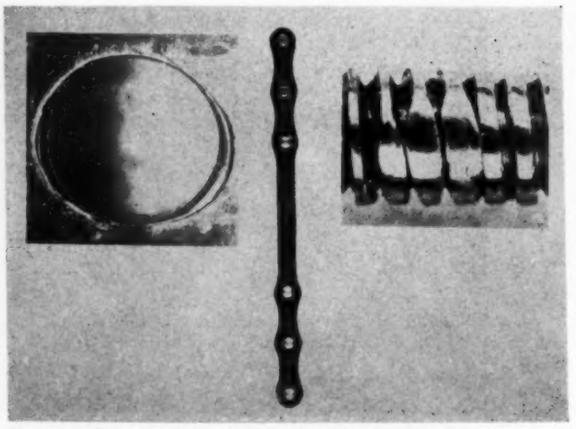


FIG. 6. Plate with enlarged photographs of part of screw and screw hole 3 showing extreme burring of the threads of the screw and the edges of the hole.

but no absorption in the distal cortex. The proximal cortex under the heads of screws B and C at the time the x-ray was taken had already lost much of its density and resistance because of the excessive forces which acted on it. As a consequence the bending stresses in these screws were concentrated in the portion of the screw in the medullary cavity close to the still dense distal cortex. This accounts for the location of the later fatigue failure in these screws.

At 282 days B and C showed advance of absorption but were intact. At 336 days there was further advance of absorption about B and C. Most distal screws show more absorption in distal cortex. At 413 days A, B and C were broken and the distal portion of the plate separated. (Fig. 3.)

The breaks in the three screws marked A, B and C are typical fatigue breaks caused by rocking of the plate on the bone which produced repeated flexural stresses in the screws which remained fixed in the distal cortex but became loose in the proximal cortex. (Fig. 5.) Although plates so grossly defective in transverse curvature are an invitation to fatigue failure of the screws, it has not always happened when such plates have been used. It is possible that failure might not have occurred in this case if the screws had been more accurately centered in the holes through the plate. Examination of these holes shows that all of them have been burred and deformed by rubbing against the screws either when the screws were inserted or after the plate became loosened. (Fig. 6.) This is confirmed by the observation that some part of the threads of all except one of the seven screws sent to the metallurgist were burred.

In other patients, in some plates which were removed because the screws became loose burred holes and burred threads on the screws were noted which were believed to have been inserted through the burred holes. In some of these there was no doubt that the burring was caused by inserting the screw in a pilot hole in the bone which was not concentric with the hole in the plate.

The edges of the slots in the heads of all the screws were upset and marred and gouged by the blade of the screwdriver. (Fig. 7.) The marring and gouging are presumably to be explained by slipping of the blade in the slot but the upsetting can only be explained by the application of excessive torques in inserting or tightening the screws. The excessive torques may have been made necessary because of pilot holes in the bone too small for the screws or because they were not concentric with the holes in the plates.

Excessive torques in tightening the screws do not increase their holding power but actually decrease it by exerting undue pressure on the bone. It is even possible to use sufficient torque in tightening the screws to break off the threads cut in the bone and completely destroy their holding power. No more torque should be used than is necessary to seat the head of the screw snugly in the countersink in the plate. However, no corrosion was found about any of these heads.

This metallurgist has been worried to think that there were sure to be more failures from the same causes with their concomitant reoperations, prolonged hospitalization and even poorer final results. Even if defective plates

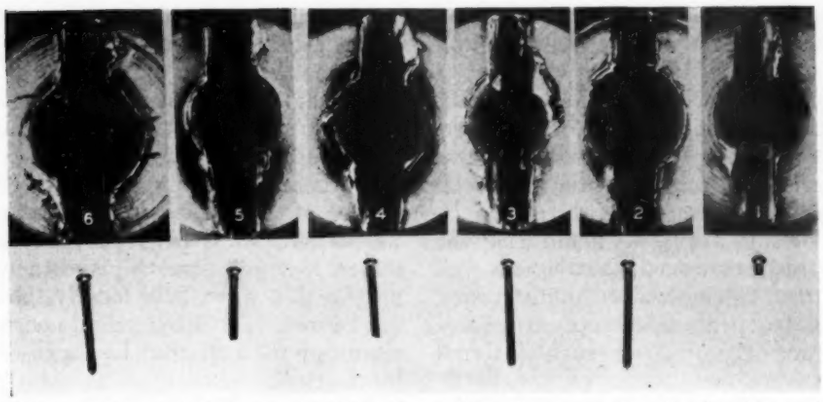


FIG. 7. Enlarged photographs of the slots of the six screws showing burring and upsetting.

and screws are not used, trouble can be caused by faulty technic in applying perfectly good plates and screws. Dr. Leonard T. Peterson's article[1] in addition to describing good technic points out some common faults in application. It does not, however, emphasize the seriousness of the results which can be caused by such faults.

SUMMARY

Some of the various mechanical problems in open reduction of fractures have been mentioned. A case has been presented in which a plate loosened, screws broke and non-union occurred. We believe this was due primarily to use of a plate with insufficient curvature the rocking of which caused fatigue failure with breaking of the screws. This rocking also caused loosening of some of the screws. The burring of plate holes and screw threads suggests that the screws may not have been centered in the plate holes accurately. The upsetting of the slots in the heads of the screws means that excessive torque was used in inserting or tightening the screws. To obtain the desired result greater attention needs to be given to the basic details of choice of and application of plates and screws.

REFERENCE

1. PETERSON, LEONARD T. Fixation of bone by plates and screws. *J. Bone & Joint Surg.*, 29: 335–347, 1947.

DISCUSSION OF PAPERS BY DRS. KERNWEIN AND CAMERON, HAMMOND, BUTLER, GASTON, SMITH AND BAAB, MORRISON AND ADAMS, AND KENNEDY AND STONE

JAMES J. CALLAHAN (Chicago, Ill.): Dr. Kennedy is to be congratulated for bringing such an important paper to our attention. With the exception of errors in technic in the application of the plates, we have already experienced the serious complication of having the screws and plates break.

I would like to call your attention to another fact, that is, the drill point which frequently breaks after multiple sterilizations. Recently the manufacturers have been trying to improve the material and quality of the drills and I believe the Collison drill at the present time is probably the best. While it will not break, it will bend and thus not hold a sharp edge. In fact, after three to four sterilizations it becomes very dull.

A point I would like to emphasize is that we frequently find broken drills in the bone following surgery. I think we should make an effort to remove the drills when broken instead of leaving them in. I know that I have been guilty of this habit but in recent years I have tried to remove any drill that is broken. There is a little apparatus similar to a trephine that assists in removing the broken drills.

A general plea should be made to the manufacturers to make better metal plates and screws. In a review of many of the plates and screws it was found that they were defective either in the flutes, threads or that the depression of the head was either too deep or not deep enough. In other words, they were not uniform or to specification.

It is hoped that Dr. Kennedy's constructive criticism will do much to eliminate the defect now present.

G. EDMUND HAGGART (Boston, Mass.): I personally feel indebted to Dr. Kennedy for bringing the fact home to me that insufficient transverse radius of curvature of the wide part of the plate is of such significance.

I wish, however, to ask him a question. I have the penny test down all right but is that on the whole quite adequate to settle that particular point? Secondly, what suggestion may he have as to how we could check our screws other than our own observations? Are there any special precautions we could utilize?

I am in complete accord with Dr. Callahan about the bits. They have been a source of considerable distress to us.

Finally, I was impressed with the point Dr. Kennedy made in this particular case of his. There was no electrolytic action whatsoever so that it was apparently a mechanical fault essentially in relation to this inadequate curvature of the plate.

In conclusion I would like to say again what the previous speaker just mentioned; that is, it is well and better than that to emphasize the distressing results that occur from improper application and inadequate training in utilizing such internal fixation.

GEORGE J. CURRY (Flint, Mich.): I wish to make a few remarks about the presentation that has been given by Dr. Gaston. The principles that he has outlined are very basic and the follow-up studies most convincing. They are characteristic of the efficiency of the Presbyterian Hospital Fracture Service.

I reviewed seventy-five consecutive radial head fractures extending over a period of four years and the evaluation of these cases is very similar to the classification that Dr. Gaston has presented. Eighty per cent of them were non-displaced, consisting of the type of fractures that he demonstrated in his first illustration. The remaining 20 per cent were displaced fractures.

The rationale of treatment of the non-displaced types in our community with many doctors taking care of fractures of this sort has been the reverse of Dr. Gaston's presentation. Fixation of the elbow at 90 degree flexion in various types of fixation apparatus, i.e., a posterior mold or a light circular plaster or a sling for a week or two was the method of choice. Early active motion was urged. That seems to be a pretty good policy in a hospital where you do not have the exact and efficient follow-up that is so characteristic of the service that Dr. Gaston represents. The results were good for the most part, complete function returning in a few weeks to a few months. Joint aspiration was done in a few cases in which pain was an important factor.

Displaced fractures indicate removal of the radial head. The two types have been mentioned together with the technic advised. This opinion is universal.

I would like to ask Dr. Gaston two questions. When do you call a fracture of the radial head displaced? What are your criteria? What would you do with that last bad case that you showed in group III if it came to you at two weeks? Would you take out the radial head then or would you wait? And if you waited, how long would it be?

I would like to compliment Dr. Gaston for an excellent presentation.

J. HUBER WAGNER (Pittsburgh, Pa.): I have been asked to discuss Dr. Kennedy's presentation. I think that he has brought out the essential facts regarding the use of the proper plate and screws so far as the centering of the hole in the plate and so far as the screws are concerned.

During the war, of course, the manufacturers of these plates were not very careful as to the making of the screws and many of them were burred. If the screw is burred, a simple test for this, as asked for by one of the gentlemen, is to take one before you use it and put it between your thumb and forefinger. If it rolls smoothly and there is no catching on the skin when held loosely, you will find it is not burred. If it is burred, of course, it is going to ream out the hole that has been originally placed by the drill.

As to the drill size, of course, one should be prepared before one attempts to do any plating to make sure that his drill is at least one sixty-fourth smaller than the screw he intends to use if he expects to get any purchase.

In the particular case that Dr. Kennedy presented I think, first, there was a very poor choice of plate. He brought out the improper curvature. That is a factor. There have been many flat plates used with excellent results but, mechanically, the proper curved plate is the one that gives the better holding and should be used. In this case, too, the plate was too short. If I read the x-ray properly, there were two fractures of the femur and the upper fracture had no fixation whatever. Is that not where the non-union took place?

The external fixation after the internal fixation was improper as one could see. The stress was on the upper screw. It pulled out and then the fatigue strain naturally came on the other two screws. It was purely mechanical.

KELLOGG SPEED (Chicago, Ill.): At the risk of having the hammer pulled on me again, I would like to introduce at this time the fact that there is a revision about to be attempted in our nomenclature of fractures. Committees have been appointed from various surgical bodies to attempt a complete and searching revision of all the forms and types and so forth.

In that connection if we care to call the fractures at the lower or distal end of the radius all by one name, that name should be pronounced properly. The name is not "Collēs." The man's name was pronounced Kólez with the accent on the first syllable.

BOARDMAN M. BOSWORTH (Bronxville, N. Y.): I was particularly interested in Dr. Gaston's group III cases with reference to myositis ossificans. The reasons for the occurrence of myositis are the reasons usually given, namely, the raising and tearing of the periosteum and infiltration of the muscles with hemorrhage.

I would, therefore, like to have Dr. Gaston explain to me why early operation will obviate the occurrence of ossification later. As I recall he said that in the operation which he does the fascia is

not closed but the skin is. How can this obviate the underlying disorder? I would also ask him to tell us what he does when the myositis has occurred; how does he treat those cases?

With reference to Dr. Adams' paper, which I very much enjoyed, I used to be a Roger Anderson enthusiast in the early days and I became very anxious to use these pins in the femur. I used them in just one case. That turned out to be a terrific headache, about the worst result I recall having had on my hands.

James K. Stack (Chicago, Ill.): I would like to discuss Dr. Butler's paper. I enjoyed it very much.

However, I think he is in some instances too radical. The subject of arthritic change in the wrist following non-union of the navicular with subsequent ulnar displacement of the lunate as necrosis takes place has interested me for a long time. In the *Annals of Surgery* for August, 1948, there is an article reviewing the results of the excision of the proximal row of the carpus for this condition in which we believe that it is a worth while procedure and much better than fusion of the wrist in these selected cases.

When arthritic changes take place following necrosis of one or both fragments of the navicular, the greatest change occurs on the radial side. You all know of the osteophytic spike that occurs at the styloid of the radius; only a minor change will take place in the early cases in the really important part of the articular surface of the radius so that the navicular, both fragments, and the lunate may be removed and the capitate or the os magnum will come down in a matter of ten days or two weeks and give what we think is a very satisfactory wrist. Of course, there will not be a complete range of motion but it has not been our experience in the cases that have been well chosen that these people have prolonged pain or weakness.

In two of our patients, this was done bilaterally. One patient was a railroad fireman who is still working and another was a dentist who is still practicing. You will grant that one must have a reasonable degree of stability, painlessness and strength in order to accomplish this.

There is no other place in the body where we can get such good conditions for an arthroplasty. The cartilage of the os magnum or the capitate is usually undisturbed and only minor disturbances have taken place on the articular surface of the radius so that it requires no interposition of fascia or synthetic material. Furthermore, the patient is protected from then on against the cystic and arthritic change that would otherwise occur over a period of years.

We have cases that have been seen for as long as thirty-five years, and those which were reported were followed for not less than ten and for as high as thirteen years. I commend this procedure to you, therefore. It is something that at least should be thought about because the average patient will shy away from any procedure which requires the stiffening of a joint and we can give them a reasonable range of motion the other way.

Laurie H. McKim (Montreal, Quebec): I wish to take just a moment to compliment Dr. Gaston, the author of the paper on fractures of the head of the radius, on the excellence of his paper and also to make a few inquiries.

I understood Dr. Gaston to say that he operated upon all of his patients, when possible, within twenty-four hours. He also stated that 50 per cent of all those operated upon after twenty-four hours developed myositis ossificans, better known as calcifying hematoma. The statement was also made that 50 per cent of all patients developed bone at the site of excision of the head of the radius. These statements are in such startling contrast to the figures of the group with which I have been associated that I would like to know if there is a common factor that is the cause of the difference.

It has been our custom not to operate in the first twenty-four hours but rather to operate at the end of four to five days when things apparently had quieted down a bit. Secondly, we have been in no hurry to start movement in the first twenty-four hours or anything near it but rather at the end of a few days and then only within limit of pain.

I have yet to see in one of the cases handled in that manner bone development at the site of excision of the head and I have yet to see my first calcium hematoma in those cases. Therefore, I would like some discussion of this question of the early or late operation as has been brought out also by Dr. Bosworth.

As to the other point (physiotherapy), the late Dr. Fraser Gurd used to state that when he was asked the question when he would refer any elbow case to the massage department, he said, "Any time after the eighth month." That was merely his way of impressing people with the idea that you did get calcifying hematoma around the elbow joint following early movement.

I would like to ask a second question of Dr. Gaston. Did the patients who developed this amazingly high percentage of calcifying hematoma and new bone formation have early massage?

The third question is, what per cent of those minor fractures in which the head was not removed but early movement was started developed calcifying hematoma?

Henry C. Marble (Boston, Mass.): I would like to discuss briefly the phonetic spelling of the name Colles. The gentleman in question deserves consideration. We pronounce his name in two syllables. Whether you call it Collēs or Colles, the main thing is that he did pronounce his own name in two syllables. He wrote one article on fractures in his entire life and that is the article we all know.

I am going to visit the shrine of the great Irish

surgeon next fall and if I can find any of the Colles family in existence, I am going to take my dictaphone and have them inscribe on a wax cylinder, in proper phonetic enunciation, exactly the way that we Americans should pronounce the name in the future.

FRANK E. STINCHFIELD (New York, N.Y.): I would like to say a few words about the first two papers. Dr. Kernwein presented a most interesting series of spine fusions in which metal screw fixation was used. I am sure that he is basically correct when he states that the end result must be judged not so much on bony union but on the presence or absence of pain and the patient's ability to return to his former occupation.

However, it would seem that a word of caution should be interjected regarding internal fixation in spine fusions. Technically it is not too easy to insert the screws in the ideal position. Also a great deal of holding power is being required of a relatively small facet area. The long leverage arm above the area of fusion exerts a tremendous force on the short leverage arm produced by the screw fixation. Physiologically and anatomically, it does not seem right to do a spine fusion and have the patient out of bed in twenty-four hours or within the first two weeks.

Three years ago we became very enthusiastic about early ambulation of patients having had spine fusions in which screw internal fixation had been used. Our percentage of pseudoarthrosis rose precipitously, coincidental with an increase in recurrence of back pain and disability. In a large series of reported end result studies of spine fusions it was found that 50 per cent of pseudoarthroses were asymptomatic.

The only way to tell accurately whether or not a pseudoarthrosis exists is to obtain flexion extension and lateral bend x-rays. The conventional anteroposterior and lateral stereoscopic views frequently fail to show a definite pseudoarthrosis.

Dr. Kernwein has presented an excellent paper and his results speak for themselves.

Dr. Hammond presented an exceptionally fine method of dealing with the comminuted Colles' fracture and one which will be of benefit to all. His results as shown and stated leave little to be desired.

In a comminuted Colles' fracture one must exert traction and countertraction to effect the reduction and then must maintain these forces until enough new callus forms to prevent recurrence of deformity. I know of no satisfactory, comfortable, safe way of accomplishing this other than by the use of wires.

At times we have varied the technic as described by Dr. Hammond. Rather than extending the plaster above the elbow to effect countertraction, we have placed a wire through the olecranon and, after reduction has been accomplished, include both wires and yokes in the circular plaster. In this manner the elbow is left free to move. Since the method as described by Dr. Hammond has been used, the end results have been greatly improved.

It was a pleasure to hear both of these excellent papers. Thank you.

GRAHAM A. KERNWEIN (closing): I wish to thank Dr. Stinchfield for his remarks. I am aware of the work to which he refers but I reiterate that it differs from our experience. We find that with early ambulation patients get up, return to their occupation, do their usual work and state they are comfortable.

The question of whether or not a pseudarthrosis is present is more academic than practical. The fundamental question is whether or not the patient has been relieved of pain and can he do his work. We find the vast majority can.

GEORGE HAMMOND (closing): I wish to thank Dr. Speed and Dr. Marble for their discussion of the proper pronunciation of the C-o-l-l-e-s fracture. I am sure that we will all be anxious to hear Dr. Marble's report on the pronunciation next year.

I wish to thank Dr. Stinchfield for his remarks. Elbow joint motion in the elderly patient has not been a problem with the treatment as outlined. It was surprising to me that these elderly patients mobilized their elbows so easily and quickly after the long arm cast was removed.

A. A. BUTLER (closing): I would like to thank Dr. Stack for his remarks. I listed ten indications. He has criticized one, so on the basis of that, I assume he agrees with the other indications.

This question of arthroplasty of the wrist is one that I have looked into a good deal and I have seen good results with it but not for the cases of fractures of carpal scaphoid in which we have gross osteo-arthritis involving the entire carpus. That is a different group, I think, from the ones to which Dr. Stack is referring.

In the R. A. F. we estimated that we had over 800 fractures of the carpal scaphoid and that over 200 of these were seen at too late a stage to produce a good functional result. That group plus the group in the subsequent three years represents a very large number. There have been twenty-one cases in which the gross osteo-arthritis has been severe enough that we have considered it necessary to do an arthrodesis.

Our indications are not very wide, so that I think if we analyzed our cases, Dr. Stack and I would probably agree on these. I did show one illustration of an arthroplasty, excision of the proximal row of the carpus, in which the patient had a stiff and painful wrist that required arthrodesis.

R. H. KENNEDY (New York, N.Y.): May I ask one question before Dr. Gaston closes the discussion? I understood him to say that the excision of the head was done proximal to the orbicular attachment. I would like to ask him if I understood him correctly.

SAWNIE R. GASTON (closing): That is correct.

I appreciate very much the interest which has been shown in this paper and wish to thank the discussers. I thank Dr. Curry in particular for his generosity. In answer to his question about what comprises a displaced fracture, I tried to avoid in the article a metric definition thinking that it might be better if we had a functional concept of the duty of the proximal radio-ulnar joint in terms of its circumferential pivotal anatomy. If a fragment is sufficiently out of place to interfere with rotation, flexion or extension, the head should certainly be removed. However, if we are to choose a metric definition of displacement, let us say that if more than 25 per cent of the articular surface of the head is separated or displaced more than 2 mm., that head should be removed.

In answer to the second question proposed by Dr. Curry, what would one do with a fracture in the group III classification seen first by the surgeon two weeks after injury, I think it would be best if that elbow were not operated upon. I think every effort should be made to gain as much function as possible by active motion. If, after four months, motion was still limited and the patient was complaining of symptoms, and if by x-ray there was no evidence of early myositis ossificans, I think that the head could be removed at that time. If there is evidence of myositis ossificans, I think it would be very unwise to operate before a year or possibly two. Judgment would depend upon x-ray evidence of the increase in the amount of calcium present by successive examinations; and when the amount of calcium has appeared to reach a stationary level and then begins to decline in amount, it would be safe to excise *en masse* the antecubital calcification.

In answer to Dr. Bosworth's and Dr. McKim's remarks about the myositis ossificans, I know of no explanation why bone forms in the soft tissues. I don't think that problem has ever been elucidated to everyone's satisfaction. Whether it is in the muscle of the thigh or any other part of the body, it is a mystery. We do know enough about bone healing, however, to know that the acid pH of the blood is of some consideration and that the presence of a local source of calcium in the form of bone fragments is of consideration as are also lacerated muscle, fascia and periosteum.

Why operate in twenty-four hours? This situation of potential bone-forming elements is eliminated in large part by immediate operation. The fascia is left open so that the tissue fluid and tension in the antecubital fossa can be decreased by leaking out and possibly that may have some bearing in terms of pH that discourages bone formation.

GORDON M. MORRISON (closing): Dr. Kennedy and Dr. Stone are working on a problem that certainly interests me because in the last year I have had at least six screws break. I am more than grateful to these men and I hope they keep up the good work.

If I might say a word about Dr. Gaston's paper which I admire very much, I would like to add that his remark that the decision to operate or not to operate must be immediate, is certainly a good thing for us all to remember. The sad results that we have had have all developed from changing our minds three or four or six weeks after the original injury.

Concerning the paper Dr. Adams gave, I am coming to believe that on femoral shaft fractures that are to be plated perhaps we would do best to put on a massive bone graft as a primary affair in the first place and be done with it.

MEYER M. STONE (closing): On behalf of Dr. Kennedy and myself I want to express our appreciation for the kind remarks made by Drs. Morrison, Haggart, Wagner and Callahan. It certainly is an incentive to go on with this type of work.

With reference to Dr. Haggart's remarks about screws and how one can determine whether a screw is good or bad, Dr. Wagner gave us some hint about that when he said: "Roll the screw between your fingers and see if any burrs or filings are in the threads." If there are, the screw should be discarded because it will ruin the hole drilled in the bone. If the flutes are unusually long or irregular, the screw should be discarded. I have examined flutes in some screws that ranged from $\frac{1}{8}$ to $\frac{3}{8}$ of an inch in length with marked irregularity. They limit the holding power of the screw in the distal cortex if that screw is not passed beyond those flutes in that distal cortex. The screws should fit loosely through the holes in the plates and thus prevent any contact with the sides of the plate and cause flattening of the threads as they go in.

Dr. Wagner made the remark that our plate was too short in this particular instance and that there were two fractures. Let me correct him if I may. There was but one fracture and a loose fragment. The loose fragment was held by three transfixion screws and the plate applied after the loose fragment had been fixed.

As to the length of the plate, the one used was the longest plate that was available at the time in an 18-8 SMo. We certainly believe that a longer plate might have given us better results. That is a matter that is open to question and we believe that failure here is primarily due to the radius of curvature of the plate being entirely too large.

In reference to Dr. Callahan's remark on the drills, he is perfectly correct in saying that the Collison drill, as is used by us at the present time, does not break but bends and dulls rather quickly. A broken drill point should not be left in, that is, the usual high-speed drill, because it is a dissimilar metal as compared with the composition of the plate and screws. This may result in setting up an electrolytic reaction with an adjacent screw or the plate which we have seen occur.

FARM ACCIDENTS

A CLINICAL AND STATISTICAL STUDY COVERING TWENTY YEARS*

R. A. CALANDRUCCIO, M.D. AND JOHN H. POWERS, M.D.

Memphis, Tennessee *Cooperstown, New York*

ONE hundred thousand needless accidental deaths occur in the United States each year. Four thousand five hundred of these, the greatest number of occupational deaths in the country, are among farmers.[1] For every fatal accident there are approximately 100 serious, disabling but nonfatal agricultural injuries which often require weeks of hospitalization and months of convalescence before rehabilitation is complete.

This report is based on a review of 658 accidents of this type during the years 1929 to 1948 inclusive. The patients were treated at the Mary Imogene Bassett Hospital in Cooperstown, a medium-sized general Hospital equipped with all facilities for modern diagnosis and therapy. A previous survey of farm injuries from this institution[2] was published for the years 1929 to 1938 and the data from this earlier report are included in the present survey. Subsequent to the initial report from Cooperstown, Creevey published a similar study from the Mary McClellan Hospital in Cambridge, New York.[3] Since the methods of farming in this area are similar to those in the central part of the state, Creevey's statistics have occasionally been utilized for additional comparisons.

ANALYSIS OF 658 FARM ACCIDENTS

Incidence. During the first decade embraced by this study (1929 to 1938) 1,329 patients with serious injuries from all types of trauma were admitted to the Bassett Hospital; 310 of these, or 23.3 per cent, were related to the hazards of farming. During the second decade (1939 to 1948) there were 1,805 admissions due to accidents, of which 348 were agricultural, an incidence of 19.3 per cent. During both decades farm accidents were responsible for 20.9 per cent or one-fifth of all admissions caused by trauma. Only 34 per cent of these patients received professional care before arrival; 17 per cent were given some first aid by laymen and 49 per cent had no medical attention.

Seasonal Distribution. Curves representing the seasonal distribution of all farm accidents during each of these two decades are similar and also are quite comparable to the curve for all rural accidents (Fig. 1) reported at the Conference on Rural Medicine in Cooperstown in 1938.[4] The peaks during July and August are composed largely of accidents due to haying, those which occur during the repair and construction of building and those in which children are involved while at play around machinery in operation, men at work, farm animals and buildings. Accidents in the course of routine chores are fairly constant throughout the twelve months while those due to logging occur most often during the late fall and winter. Summer is obviously the most dangerous season on the farm, late winter and early spring the most secure.

Location. In the original survey of 310 farm accidents during the years 1929 to 1938 the barn and barnyard were found to be the most dangerous localities on the farm. (Fig. 2.) Accidents on the highway did not include mishaps to farmers as pedestrians or while riding in motor vehicles for pleasure but were limited to those which transpired during hours of work with animals or farm machinery. A few accidents occurred in the farm house and shed, 6.8 per cent, which should perhaps be more properly designated as "home accidents on the farm" rather than strictly "farm accidents."

A very close correlation was found among the 348 accidents during the years 1939 to 1948. Related sites have been grouped and are tabulated for comparative study in Table 1.

Etiology. At least two factors participate in the causation of most farm accidents, a motivating activity and a causative agent. In this analysis of etiologic factors the cases reported by Creevey from the Mary McClellan Hospital have been included with those from the Bassett Hospital and bring the total number available for study to 1,028. The data are

* From the Department of Surgery of the Mary Imogene Bassett Hospital, Cooperstown, N. Y.

presented in tabular form and include both the number and percentage of accidents in each series which were induced by each activity and caused by each agent. (Tables II and III.)

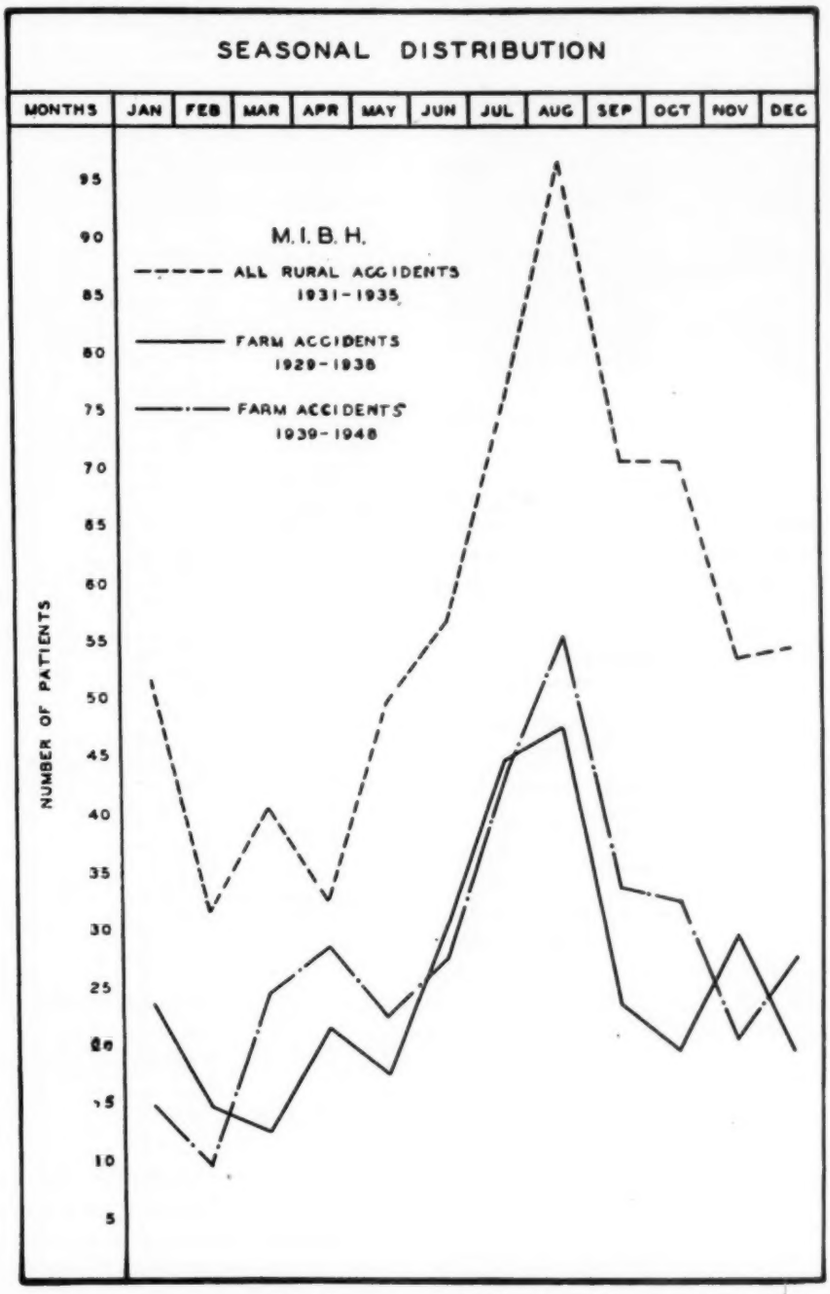


FIG. 1. Curves representing the seasonal distribution of farm accidents during the decades 1929–1938 and 1939–1948 compared with the seasonal distribution of all rural accidents from 1931–1935.

Routine farm chores were responsible for about one-third of the 1,028 accidents (Table II), logging and haying for one-sixth each. Approximately the same number were sustained by children while at play. "Assault or suicide" may be questioned as a hazard of farming but the authors believe that both are occasionally induced by the lonely life of poverty and solitude which many farmers lead in distinctly rural areas and so should be included in this survey.

The etiologic agents are recorded in Table III. Farm animals were responsible for the largest number in the total series. Three-

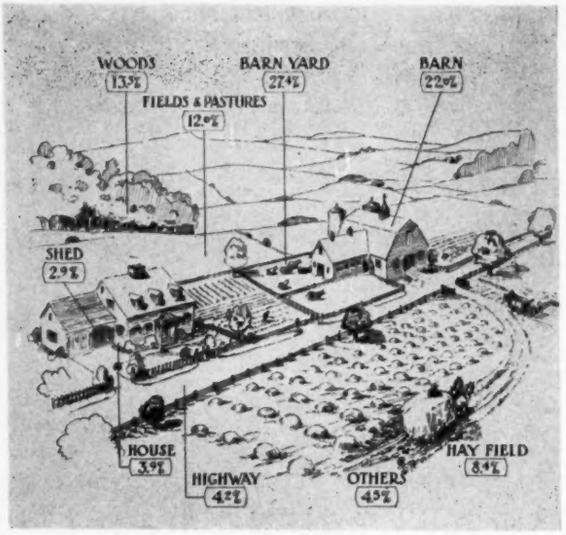


FIG. 2. Illustrates the location of 310 farm accidents during the decade 1929–1938.

fourths of these were caused by horses; one-fourth by cows and bulls. Tools and implements were the offending agents in 15.7 per cent of the injuries, the axe and pitchfork most often

TABLE I
LOCATION OF FARM ACCIDENTS*

Scene of Accident	Per cent of Farm Accidents		
	M. I. B. H.		
	1929 to 1938	1939 to 1948	Average
Barn or barnyard	50.0	51.6	50.8
Fields and pastures	21.0	22.1	21.5
Woods	13.5	8.5	11.0
House and shed	6.8	8.1	7.5
Highway	4.2	4.7	4.4
Others	4.5	5.0	4.8
Total	100.0	100.0	100.0

* Comparative tabulation by decades of the location of 310 accidents during 1929 to 1938 and 348 during 1939 to 1948. The frequency with which accidents occurred in the same localities on the farm during these twenty years is impressive and significant.

responsible. Approximately the same number of accidents was caused by farm machinery of which the rotary buzz saw is by far the most mutilating.[5] Under "Others" are included barbed wire fences, rusty nails, splinters, thorns, hooks, chains and firearms. When a fall occurred with no obvious causative agent responsible, none was recorded; the numerous falls on slippery, icy ground account for the high percentage of accidents in the category of "Others or None."

TABLE II
ETIOLOGIC ANALYSIS OF THE MOTIVATING ACTIVITY IN 1,028 FARM ACCIDENTS*

Etiologic Activity	M. I. B. H.				M. McC. H.		Total	
	1929–1938		1939–1948		1920–1939			
	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent
Chores	99	31.9	87	25.0	129	34.9	315	30.6
Logging	66	21.3	64	18.4	51	13.8	181	17.6
Haying	50	16.1	62	17.8	52	14.1	164	15.9
Play of children	31	10.0	62	17.8	73	19.7	166	16.1
Repair and construction of buildings	22	7.1	9	2.6	12	3.2	43	4.1
Assault or suicide	13	4.2	5	1.4	16	4.3	34	3.3
Others	29	9.4	59	17.0	37	10.0	125	12.1
Total	310	100.0	348	100.0	370	100.0	1028	99.7

* Two series from the Mary Imogene Bassett Hospital (1929 to 1938 and 1939 to 1948) and one from the Mary McClellan Hospital (1920 to 1939).

TABLE III
SIMILAR TABULATION OF ETIOLOGIC AGENTS

Etiologic Agent	M. I. B. H.				M. McC. H.		Total	
	1929–1938		1939–1948		1920–1939			
	Number	Per Cent	Number	Per Cent	Number	Per Cent	Number	Per Cent
Tool or implement	56	18.1	57	16.4	49	13.3	162	15.7
Animal	51	16.5	64	18.4	50	13.5	165	16.0
Machine	40	12.9	39	11.2	58	15.7	137	13.3
Vehicle	36	11.6	35	10.0	29	7.8	100	9.7
Falling tree	17	5.5	18	5.0	16	4.3	51	4.9
Heat or cold	7	2.2	2	0.6	21	5.7	30	2.9
Others or none	103	33.2	133	38.2	147	39.7	383	37.2
Total	310	100.0	348	99.8	370	100.0	1028	99.7

Analysis of the Accident to Admission Interval. The length of time required for injured farmers in the surrounding countryside to reach the hospital after an accident has occurred may be influenced by the season of the year, the condition of the roads and the distance to be traversed, the availability of transportation, the severity of the injury and the attitude of both the patient and

his doctor, if any, toward the necessity for hospitalization.

The solid black line in Figure 3 published previously represents the rate of admission during the decade from 1929 to 1938; the broken line represents the same for the subsequent ten years. It is interesting that in spite of the many variables mentioned previously the two curves can be almost superimposed. Numerous improvements in rural living during the second decade have not been reflected in the rapidity with which farmers in central New York are admitted to the Hospital after injury. During both decades approximately 30 per cent arrived within one hour, 45 per cent within two hours, 55 per cent within four hours and 62 per cent within six hours. The percentages for subsequent intervals from one day up to one week are tabulated in Figure 3.

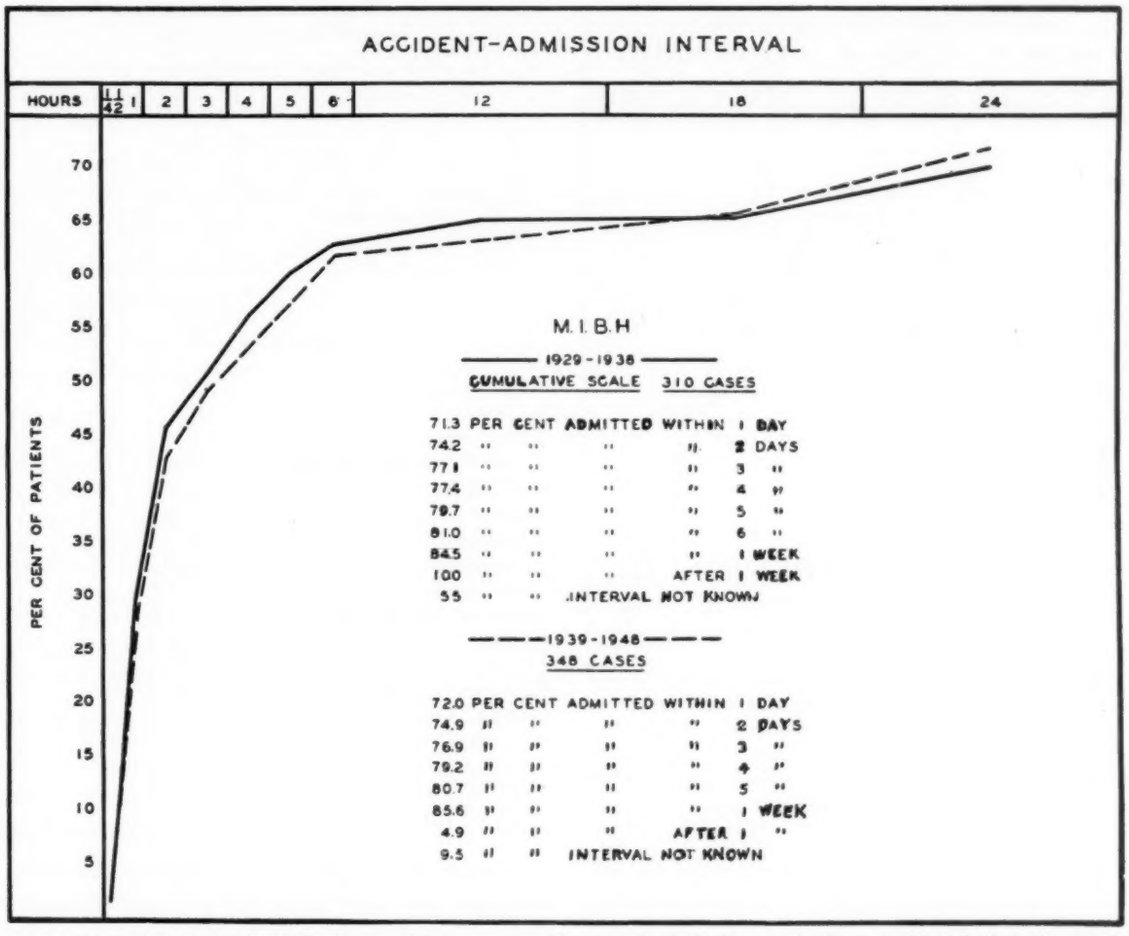


FIG. 3. Graphic analysis of the interval between accident and admission to the Bassett Hospital during each of the two decades in the survey.

Age-Incidence. During the years 1929 to 1938 farmers between the ages of ten and fifty were most frequently injured in rural accidents. This type of curve, indicated by the solid black line in Figure 4, has previously been reported by Powers and Creevey and represents the usual age-distribution of accidents on the farm. The curve representing the age-incidence during the subsequent decade from 1939 to 1948 shows very distinct variations from the normal. This period embraced the war years when men between the ages of twenty and twenty-nine had left the farms for the armed services and many of those between forty and forty-nine were more profitably employed in munition plants and other essential industries. Many of those between thirty and thirty-nine years of age who were unfit either for military duty or industrial labor were capable of farm work and obtained agricultural employment while those between the ages of fifty and fifty-nine who in normal years would have retired continued at work to

supplant younger men in the services and war plants. These suggestions may serve to explain the dissimilarity in the curves representing the age-incidence of farm accidents during the first and second decades of this survey.

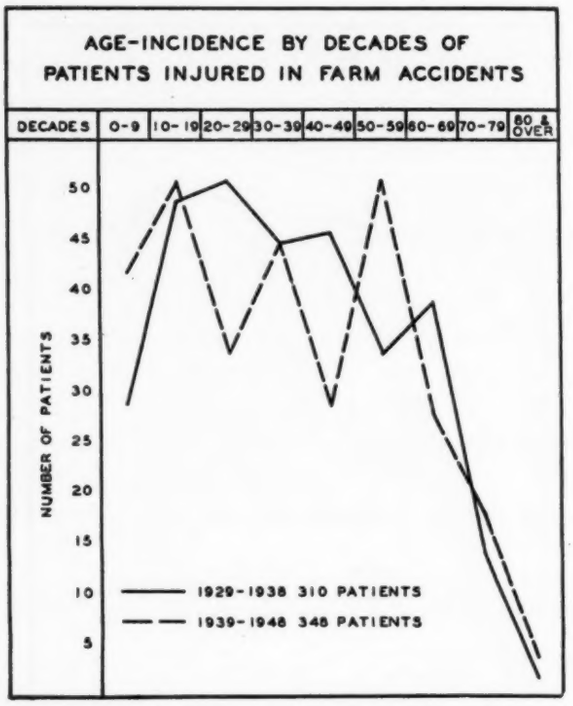


FIG. 4. Graphic representation of the distribution of farm accidents according to the ages of the patients injured. The reason for the dissimilarity of the curve for the years 1939–1948 when compared with that for the previous decade is suggested in the text.

Classification of Injuries. During the twenty years from 1929 to 1948 the 658 patients treated at the Bassett Hospital as a result of farm accidents sustained 1,527 recorded injuries classified according to the Standard Classified Nomenclature of Disease. These are listed and tabulated in order of frequency in Table IV. In actual numbers there were 488 fractures of which 134, or 27.4 per cent, were compound. Lacerations were next in frequency. Division of nerves, tendons and blood vessels and partial or complete amputations of fingers, hands, forearms and legs were common and were due to contact with rotary saws, mowing machines, ensilage cutters, scythes and axes. Punctures were caused by hay forks, manure forks, rusty nails, barbed wire fences, thorns and splinters. The upper extremities were injured most frequently, the lower extremities last.

Period of Hospitalization. During the first decade embraced by this study, 1929 to 1938, the average period of hospitalization as a result of farm accidents was 18.3 days; during 1939 to 1948 the average was 14.1 days, a decrease of 23 per cent. This represents an average of 4.2 days per farmer-patient, a distinct saving in both time and money. Open reduction and internal fixation of fractures, the liberal use of chemotherapeutic agents and antibiotics and prompt ambulation whenever possible after injury have been responsible for the current modifications in convalescent care.

TABLE IV
TABULATION OF 1,527 RECORDED INJURIES IN ORDER OF FREQUENCY OF OCCURRENCE

Classification	Per cent of Farm Injuries		
	M. I. B. H.		
	1929 to 1938	1939 to 1948	Ave. 1929 to 1948
Fractures	33.7	30.0	31.7
Lacerations	14.5	14.0	14.2
Divisions or amputations	10.6	5.9	8.2
Contusions	7.8	6.2	7.0
Incised or punctured wounds	7.4	6.6	7.0
Abrasions	6.1	4.9	5.5
Concussion	4.1	5.7	4.8
Dislocations	4.1	4.1	4.1
Burns or frost-bites	3.5	2.4	2.9
Shock	2.1	1.1	1.6
Compressions	0.6	0.7	0.7
Gunshot wounds	0.6	1.1	0.9
Foreign bodies	0.5	2.4	1.4
All others	4.3	15.0	9.9
Total	100.0	100.0	99.9

Analysis of Fatalities. During the years 1929 to 1938 there were sixteen deaths among 310 patients admitted to the Bassett Hospital because of injuries sustained in farming.[2] (Table v.) During 1939 to 1948 there were three deaths among 348 patients. Two of the patients who died were moribund on admission; the third death was due to massive pulmonary embolism.

The very gratifying improvement in the mortality from serious farm injuries during the years 1939 to 1948 may in part be attrib-

uted to a more thorough understanding of the physiologic alterations in the human economy effected by severe trauma, to the greater availability of blood and substitutes therefor, the extensive use of chemotherapeutic agents and antibiotics whenever indicated and to the employment of anticoagulants for the prevention and treatment of thrombosis.

TABLE V

TABULATION OF STATISTICS RELATIVE TO MORTALITY FROM FARM ACCIDENTS

1929 to 1938, 310 Patients

Cause of Death	No.	Contributing Activity	No.	Contributing Agent	No.
Fracture—dislocation of cervical spine	4	Chores	5	Animal	3
Compound depressed fracture of skull	3	Logging	4	Heat (fire)	3
Extensive burns	3	Haying	3	Vehicle	2
Multiple injuries and shock	2	Children at play	2	Falling tree	2
Tetanus	1	Repair of buildings	1	Machine	1
Peritonitis	1	Suicide	1	Firearm	1
Bacteriemia due to staphylococcus aureus	1			Others or none	4
Coronary thrombosis	1				
Total	16	Total	16	Total	16

Mortality, 5.1 Per cent

1939 to 1948, 348 Patients

Cause of Death	No.	Contributing Activity	No.	Contributing Agent	No.
Multiple injuries and shock	2	Chores	2	Animal	3
Pulmonary embolism	1	Haying	1		
Total	3		3		3

Mortality, 0.8 Per cent

1929 to 1948, Total Patients 658, Total Mortality 2.9 Per cent

Fiscal Analysis. The actual cost of a serious injury is a major financial burden to most farmers. During the first decade embraced by this study 20 per cent of the patients could pay nothing toward their Hospital bill and professional care. During the second decade, in spite of the improved financial status of most farmers, 21 per cent made no contribution toward the discharge of their professional debts. Local welfare organizations assumed the responsibility in some cases but the hospital was forced to accept a financial loss of about $15,000 or approximately 20 per cent of the total charges made for hospitalization and professional care incidental to the hazards of farming during these two decades. About 16 per cent of the patients paid a portion of their bills and approximately 57 per cent discharged their financial obligations in full. Nine per cent of the bills were paid by compensation insurance carriers and 6 per cent only by the Blue Cross or similar organizations. Group insurance for both hospitalization and professional care was offered in this part of New York State in 1941 but has not been generally accepted among farmers.

SUMMARY

Six hundred fifty-eight patients with serious injuries due to farm accidents, representing one-fifth of all the admissions caused by trauma, were treated at the Mary Imogene Bassett Hospital during the years from 1929 to 1948.

Such accidents showed a definite variation in seasonal incidence with a peak during July and August for which haying, repair and construction of buildings, and children at play around farm machinery were largely responsible.

Routine chores were the most dangerous motivating activities throughout the year.

Farm animals, tools and machinery contributed their share of injuries in about equal proportions. Falls were numerous.

Exactly one-half of the accidents occurred either in the barn or barnyard.

Nearly 50 per cent of the patients reached the Hospital in two hours.

Fractures comprised approximately one-third of the 1,527 recorded injuries. Extensive lacerations, division of nerves, tendons and blood vessels, and partial or complete amputation of extremities or portions thereof were common.

The average period of hospitalization was 18.3 days during the first decade of the survey and 14.1 during the second.

The mortality fell from 5.1 to 0.8 per cent.

Many farm patients were able to pay nothing for their hospitalization and professional care.

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DISCUSSION

R. A. Calandruccio (Memphis, Tenn.): The length of time required for the injured farmer in the surrounding countryside to reach the hospital after an accident is affected by many factors, namely, the season of the year, the severity of the injury, the condition of the roads, the distance to be traversed and the attitude of both the farmer and the doctor concerning the need for hospitalization.

Despite these various factors which I have already mentioned that control the rapidity with which the farmer can get to the hospital, the many improvements that have been made in rural living in the last ten years have not been reflected in this rapidity.

The second comment I would like to make in passing is that of accident-proneness which in the last few years has gained much interest, especially concerning automobile accidents and industrial injuries. Our psychiatrists tell us that the accident-prone patient is of a certain psychic makeup, that is, in many accidents mental and physical fatigue and other external factors are not of importance but, rather, that the patient who is accident-prone is self-centered, usually does not deliberate between impulse and action; in many cases this is based upon a rebellion to authority. We have tried to find whether or not these farmers are accident-prone and if we could do something about it. Naturally, this is a very important problem.

In reviewing the 685 cases in the twenty-year period we were not able to show that these farmers show any indication of accident-proneness. The farmer is usually a very stoic man, one who must deliberate before he plants his crops and, therefore, does not fall into the psychic makeup that the psychiatrist has had planned for us.

I would like to mention one more thing that, unfortunately, Dr. Powers did not have time to mention in his discussion, that is, the fiscal analysis. Many of these farmers try as much as they can to pay their bills in full. Over 60 per cent of the total bill was paid by the farmer. Unfortunately, the farmers had not taken advantage of the various Blue Cross plans which had been offered. In our community the Blue Cross plan was offered in 1940; since that time only 6 per cent of the farmers have taken advantage of the plan.

O. Samuel Randall (Watertown, S. D.): Mechanized farming, developed so extensively in the Midwest, has not been without its toll of injuries. Injuries have been all degrees of severity, from the most trivial to actual death. In this section of the United States where the farms are quite large at least 85 per cent have mechanized equipment.

The farm tractor has been a factor in many of these injuries, due mainly to carelessness of the individual farmer and also to the failure of the manufacturers to equip these machines with proper safety devices. The farmer uses the tractor in very much the same way as a child uses a tricycle. It is not only used for many actual farm duties but also as an ordinary mode of transportation. This machine is heavy, cumbersome and top heavy and its maneuverability is somewhat limited. With proper care it can do many jobs well but if handled carelessly, can cause much damage in the field, farmyard or on the highway. Just last week a farmer was found dead under his tractor where it had tipped over on him in a ditch along the highway. This is not an uncommon type of accident. Some of the tractors are still equipped with manual starters. Therefore, we see the fractured wrist that was frequent when we started our automobiles in a similar manner.

Tractors have now been given increased speed and are, therefore, used to replace a truck for many forms of hauling such as pulling a wagon-load of grain to market, etc. But for such forms of conveyance they can easily get out of control of the driver and tip over sideways depending on any

unevenness of the ground. Some of the lightweight tractors would turn over backwards and on to the fallen driver when pulling a heavy load up a steep incline. With the added speed and more diversified uses of the tractor and with its ease of getting out of control, more accidents are being seen.

To substantiate our beliefs about certain farm machinery, Doanes Agricultural Service of St. Louis reported in the New York Times on May 22, 1949, that much farm equipment is too light, wears out too easily and certain pieces are "unsafe." They stressed the point that much equipment isn't "built to last, and that some of the machinery provided is needlessly dangerous."

The tractor is used to pull and deliver power to many farm machines and for this work it is provided with a power take-off. It is because of this power take-off that we obtain some of our most serious and frequent injuries. The injuries sustained from this mechanism vary from numerous hand, arm and leg lesions to actual death. These cannot occur when the mechanism is equipped with protective devices as most of them are today. However, as is too frequent, the operator takes this device off to make certain repairs and then leaves it off. The accident occurs when the operator comes in contact with this part of the machine while it is running. His gloved hand or trousers get caught and pull the individual into it. This connecting rod revolves at a very rapid rate of speed and if one is not able to extricate himself or if someone does not shut off the machine, he can lose his hand, arm, leg or life. The power take-off is shut off on the instrument panel of the tractor. The operator is always cautioned first to keep the safety device over this mechanism and to shut off the power take-off always before trying to make adjustments. The principle fault lies in the fact that the power take-off may still run even though the tractor is standing still with the motor going. These injuries could be eliminated if the power take-off was automatically shut off when the tractor was stopped. To do this would mean an addition to the sale price of the machine and unless all manufacturers put on the same features, there would be no sale for the machine with the advanced price. The individual operators are not interested in such safety features, not until they have lost a hand or an arm. The individual is not interested in spending money for safety.

For the same reason, the power take-off still running, we have frequent serious hand and arm losses from the corn picker machine that is being propelled by the tractor. The operator stops his tractor, motor and power take-off still running, and gets off the tractor to try to pull a stalk out of the picking rollers. It is usually in the fall of the year and he is wearing large gloves. In trying to pull the stalk out his gloves get caught and his hand and arm are quickly pulled into these rollers. A hand or arm is amputated before he can pull himself out or have some one turn off the motor.

As I have pointed out before, most of our farm accidents are due to carelessness but the farmer is no different from any other individual in this respect; he has these accidents in spite of all our educational propaganda.

These injuries which are attributed to the power take-off in one form or another are frequent and in most instances quite serious. They can be controlled or practically eliminated by the manufacturers cooperating in some simple safety measures. If the power take-off was automatically shut off as soon as the tractor stopped, the injuries could be reduced to a minimum. An officer of one of the largest farm implement companies told me recently that this could be done for about $150. As it now stands, these machines are potential death traps.

Joseph E. J. King (New York, N. Y.): In view of the fact that I was born on a farm, worked on a farm and expect to go back, God willing, Dr. Powers' paper was of special interest to me, with his beautiful illustrations, tables and plans. I have sustained every injury he enumerated there except amputation and gunshot wounds.

I will relate two little incidents about farm accidents: The first time I ever heard of a traumatic rupture of the duodenum was in a story related about thirty years ago by the late Dr. W. D. Haggard. He told of a boy about ten years old who was pushing a pitchfork down a path. He hung the pitchfork beneath the root of a tree, jabbed himself in the belly with the end of the handle and sustained a tear or rupture of the transverse portion of the duodenum.

In 1933 at a meeting of the Southern Surgical Association a paper entitled "Arachnidism" appeared on the program. I had not the slightest idea what it meant but from the study of zoology I knew that "Arachnida" meant the family of spiders and the word arachnoid meant like a spider web. I heard the paper and learned that it was about spider bites, the bite of the Black Widow, which subject was most intriguing. The essayist reported five cases and his reason for so doing was that usually the patient was admitted to the hospital and diagnosed as an "acute abdomen."

Several surgeons discussed the paper and reported one or more cases with identical findings. All stated that the pain in the abdomen was most intense and that even ½ gr. morphine by hypodermic administration did not relieve the pain. They informed us that the abdomen was the most rigid abdomen known to them, accompanied by severe pain but *no* tenderness. The reason for presenting the paper was to prevent surgeons from operating upon these patients in the belief that an intra-abdominal disorder would be found. All stated that the pain ceases either with or without

operation and all symptoms disappear in about twenty-four hours.

I present this story to you for what it is worth. To me it was most interesting.

JOHN H. POWERS (closing): I was very much interested in Dr. King's comments. Those are, no doubt, some of the hazards of farming in the South.

I am also grateful to Dr. Randall for calling attention to some of the injuries which may occur in an area where farming is mechanized far beyond the point where it is in central New York.

Interestingly enough, the hazards of industry, of mining and of construction have been recognized for many years, and definite measures have been adopted for the promotion of safety. In agriculture no such progress has been made, primarily because of the individualistic character of farming, especially in smaller communities. The only statistics which have been published, with the exception of two papers, have been based on *fatal* accidents and, in our opinion, these do not present the subject fairly.

I think it would be of extreme interest and real practical value, Mr. Chairman and members of this Association, if, during a period of years, surveys of farm accidents throughout the United States could be made, could be correlated and, possibly in conjunction with the Grange, some constructive steps might eventually be taken to prevent or to reduce the hazards of farming in the United States. It would seem to me to be a worth while, useful and practical project.

TRAUMATIC NEUROSIS

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ONE of the great and disturbing problems encountered by the surgeon who deals with traumatic patients is the marked incidence of incapacitating emotional states which appear in the patient following, apparently, a major traumatic incident. This problem is large because, frequently, if it is of a major psychotic nature, it may seriously interfere with the actual surgical treatment of the patient or if it is of the so-called "minor nature," it may assume proportions far beyond the actual structural incapacity provided by the physical trauma. There is also the problem of compensation which is apparently quite prominent among cases of this type. An attempt will be made in this paper to discuss some problems which have arisen of this nature and how they were handled, with the hope that the physician who encounters these cases will have a further understanding of methods utilized in dealing with such situations.

CASE REPORTS

CASE 1. A young mechanic in a large industrial plant came to the plant physician complaining of a severe, prolonged headache and dizziness. He dated the onset of these headaches back to an accident in the plant in which he had been working. Something had gone wrong in the levering process and the bar had snapped against him, throwing him to the ground and knocking his head against the concrete. "I was not unconscious but felt dizzy as soon as I tried to get up." He stated that his headaches began soon after that and he had been almost unable to work. They had been present for about a year's time and had been unresponsive to drug therapy and dietary changes. Neurologic studies by a neurosurgeon and a clinical neurologist were entirely negative. Simple reassurance had failed to help the patient. Psychiatric study revealed the following material: The patient was the youngest of five children, having two older brothers and two older sisters who were all married. The father, also a worker in the same plant as the patient, had gotten his son a job there. The father had considered himself a very religious man. He had attended church regularly, prayed with fervor and taught Sunday school; at home, however, he had been a tyrant who rarely spoke to his wife and when he spoke to his children it was only to reprove them. He died of pneumonia two years prior to our seeing the patient and approximately six months prior to the time of the accident described by the patient. The mother, equally devoted to religion, was just as incapable of practicing its precepts in her daily life. She, like the father, was never affectionate with the children, never praised them and never took their interests seriously. She seemed to believe that if through scolding, threats or cajolery she could get our patient to church, all would be well. He had completed high school and had been working in the plant with his father up until the time of the latter's death. But his dissatisfaction with life grew and following his accident his headaches made it almost impossible for him to carry on.

The patient was seen in a series of therapeutic interviews arranged at periods of once a week and of approximately forty-five minutes' duration. He soon made clear his hostility toward his father and mother for their unsympathetic attitude. He was particularly angry because they pretended to be so good, "Talking about the love of God, the need for man to pattern his life after the tolerance of Christ and preaching the need of love of one's fellow man." He added, "If they had been that cold and cruel and unfeeling toward others without acting in the name of Christianity, I might have stood it. But the hypocrisy of it all which they could not seem to see nearly drove me mad. When father used to come home from prayer meeting and start scolding, sometimes I would cry to myself; but since he has died and mother goes the same way, I can't cry. I only suffer and hate and get these intolerable headaches." At the point that he said this he suddenly stated, "I wonder if these headaches had anything to do with the accident or maybe, rather if it hasn't got something to do with this business about my father and mother." He was reassured that it would be all right for him to talk about his real feelings and the statement was made, "You really want to get well in order to be able to be happy and comfortable in your work." At this point I would like to note that as regards the neurotic it is true that his symptoms sometimes result in escape from trying situations but this is not known consciously by the patient. Any escape from life which comes through neurosis is dearly paid for by the neurotic in anxiety, physical discomfort, inefficiency and the loss of prestige which results from his inability to keep up in his work and his inability to enjoy life with his fellowmen. In our

patient it became apparent that his social adjustment was poor because all women seemed to him as his mother and sisters had been, that is, "critical, fault-finding and wanting something all the time and having nothing to give." Nevertheless he had a conscious longing for a woman's love although he had masturbation fantasies in which he was cruel to women. He had so much guilt and anxieties about these fantasies that he could speak about them only with great difficulty. We said to him, "Since you believe that women have been cruel and indifferent to you it is natural that you think of retaliation. This retaliation happens to be combined with your sexual feelings and fantasies but do not be distressed too much by this. Speak of it freely and you will see that some separation will take place between your ideas of love and your fantasies of hate."

The patient despised his work and hated going to church and finally got the courage to discuss these attitudes with his mother. She tried to make him feel ashamed but because of his discussions of these matters in an uncritical atmosphere he had gained courage and would not let himself be dissuaded by her. The result was that finally she allowed him to leave home and he got a job in another plant. He liked this better and for the first time his headaches were less troublesome. In the first few weeks of treatment his headaches were so bad that while talking about his parents and their injustices to him he would hold his head in his hands, sway from side to side and beg to be taken to the hospital to have some operation done upon him. "Any operation, there must be something in there, a blood clot or something. My hatred for things that have happened to me is intense but it can't be producing all of this." We urged him to be patient and to keep up the struggle.

After leaving his mother's home he suffered from loneliness from which he sought relief in feminine companionship. These friendships always ended disastrously because he always expected the girl to be kind beyond the possibilities of normal people. He wanted her to be a normal, active, friendly girl and yet make up to him in affection all that his mother had failed to give him. He could not bear to have her ask anything in the way of a favor from him. We said to him, "Remember you have been a deprived person both as a child and as a young man. While you believe that you have missed a great deal and have much coming to you in the way of affection and regard, you must recognize that it cannot be all one-sided. Any girl expects from you a cheerful demeanor and some consideration of her desires. If you can forget yourself a little and think of the girl, you will be rewarded by her gratitude."

The patient finally saw the point of this discussion and at the end of about two years met a girl whom he wanted to marry. By this time his headaches had entirely disappeared and he was reasonably happy at his work. He has since married and has been symptom-free and happy.

Case 11. A twenty-eight year old, unmarried young man while serving as an infantryman on the island of Okinawa, had been struck by fragments of a bomb while on patrol. He had lost the entire right frontal lobe and the right eye and had sustained lacerations of the right temporal lobe. He had gone through various hospitals and had been treated with the final, good osmetic result although his right eye was entirely gone. The patient was referred for treatment because of persistent, intense headaches and feelings of inadequacy and inferiority. He was receiving 100 per cent disability from the Veterans Administration and was trying to work in his father's insurance agency. He was constantly fearful that he would blow up in a temper tantrum, get in a fight and be injured in the head.

At the time of his initial study the patient showed no peripheral neurologic signs. Discussion was carefully led into the method of his having been injured. It was found that the patient was the youngest of two children, his older brother having been a commissioned officer in the Army with no combat experience. The patient had entered the Marine Corps at seventeen, had gone overseas and had participated in two campaigns without injury prior to the invasion of Okinawa. Two weeks before the invasion the patient had received word while aboard the invasion ship that his father had died of a heart attack. There were no means for him to communicate with his mother or to return to the United States. He had had to go into the invasion with this knowledge. The patient was quite resistive to coming for therapeutic interviews at first but gradually accepted the relationship. He was constantly hostile and suspicious, however, until I pointed out that probably his suspiciousness was due to his natural feelings in relationship to those in military authority positions and might have something to do with his relationship with his father. He then revealed that his father had been a cold, driving, dynamic and rigid individual who had demanded complete loyalty from his sons and had been utterly unable to give them any warmth, affection or support. The mother, toward whom the patient was deeply resentful but of whom he was quite fond, was a complaining, hypochondriacal individual who had constantly dominated her family through illness. About six months after the initial interview the patient revealed the actual facts of his injury, "I've never told anybody this. It is not a good story but it sounded all right, but you seemed never to have believed it. I've never understood why you didn't because it sounded all right to me, but if you want to know the facts I'll tell you." He was reassured that he could tell them only if he so desired and not because of the therapist's curiosity. It then evolved that the patient despite his prolonged combat experience had impulsively exposed himself on top

of a hill during a mortar barrage a few days after the campaign had started. "I don't know why I did it. I knew better than that but suddenly it seemed to me that I wanted to stand up and run toward them and destroy them all." As the patient talked about his troubles with his parents he became more and more convinced that his injury actually had something to do with his relationship to his father. Finally he found that he did not have to work in his father's insurance agency which had been left to him but that he could pursue his own field which was law and so emancipate himself from the ties of his mother without injuring her.

His headaches have subsided considerably except when he gets in a tight situation with a teacher whom he considers to be non-understanding, cold and demanding. It is probable that this man will eventually be able to accept his own hostility toward his father and his intense guilt feelings which apparently led to an aggressive suicidal attempt on his part during the battle.

To come back to the original questions propounded we can state that we know that these patients have been badly handled previously but can we do any better? What is the matter with them and how should they be treated? In attempting to answer these questions let us quote from a letter received from a young physician who states, "It seems to me extremely doubtful if education of the doctor along these lines is the answer to the problem. To delve into the personality of the patients who need this sort of study requires much more time, tact and patience than most practitioners have, and we cannot refer any considerable number to psychiatrists. Furthermore, as you know, the accessibilities of these facts vary very often with the intelligence of the patient. Even when the emotional set-up has been deciphered you will have to admit that you will find very much the same impasse if you were up against the same situation yourself. In other words, while some doctors may be able to analyze these neurotic factors, generally speaking, very few can alter them, and it has been my experience that understanding a situation has not always turned out to solving it." Last of all let us say that these patients are suffering from disturbances in their emotional lives; that is, the illness is wholly or in part of psychologic origin and can be satisfactorily studied and treated only if this factor is adequately handled. It is too often the major assumption of the physician dealing with the patient that the latter is "only interested in the compensation that he can get" or if he is in military service or in a similar type of situation "he just wants to get out of it and not assume the responsibility of it." Malingering or conscious utilization of a neurosis as an escape mechanism is a very infrequent pattern. The automatic hostility of the physician toward the patient is the thing that so often blocks the adequate treatment of these conditions. It is true that a simple understanding of the underlying psychopathologic condition does not in itself cure the patient. In other words, besides excluding physical disease in the one patient and correctly evaluating the part it plays in another, it is of greatest importance to know the patient's ability to adjust to certain life situations and his pattern of reacting to them, with the real anxiety in his make-up and the nature and seriousness of his conflict. Psychosomatic study is necessary if we are to establish a specific relationship of the psychic situation to the personality of the individual. Just as the typhoid bacillus, specific for typhoid fever, depends upon the susceptibility of the individual, so does specificity of the psychic event depend upon personality structure of the person. To make such studies one must have some training in psychopathology. One must also know something about the technic of psychotherapy.

In closing let us state that an integrated approach to the study of these patients both from the surgeon and the psychiatrist's standpoint must be carried out without automatic hostility on the part of the attending physician. Too much has been said about the art of medicine with a rejection of the fact that psychotherapy is much more than simple reassurance. It is an attempt to understand the psychologic foundations of the individual personality with guidance and help on the part of the physician that the patient himself may understand his own trends, needs and anxieties. If this approach is possible, it is believed that much of the so-called compensation and medicolegal problems incident to the traumatic neurosis will solve itself in that the patient will not seek that method of protecting his repeatedly injured self-evaluation and pride.

DISCUSSION

HENRY C. MARBLE (Boston, Mass.): When this paper which you have just heard arrived in my office about a week ago, my secretary read it—she reads all my mail. When I arrived, she put it down on the desk with a bang and said, "What have you got to do with that?"

"Got to do with what?" I said.

"That!" she said.

Well I got it out and read it myself and at first I thought somebody was playing a joke on me because when I graduated from medical school, I am perfectly sure that if they had taken a vote as to who was least likely to be a psychiatrist, I would have gotten most of the votes. But then I read it again and I read it again and the more I read it, the more interested I became in it.

Once upon a time I tried to write an article entitled, "What is the Cause of Accidents?" Well, of course, accidents just happen. Before I knew it, I was into psychology so deep that I just had to back out.

Why do accidents happen? Accidents happen because the man is inattentive, the man is thoughtless, the man is angry; the man has something that takes him away from the ordinary course of his daily work and gets him into trouble.

Well, he has an accident and he comes to the doctor. The only part of this with which I want to disagree is that, in my opinion, this *is* a job for the doctor. A psychiatrist has given it to you but, after all, he is a doctor. In our ordinary practice these cases are just as much a part of the doctor's job as to set a fracture, to sew a wound, to heal the other part. It is just as much his job to know who the patient is and what the problems of the poor fellow down in the bed are. Is his wife going out with the milkman? Is the job going to be open for him when he goes back? Is he going to get his money? What is happening to him now that he is getting $28.00 a week when he used to get $100.00?

He is worried and fearful. The element of worry and fear piles up and that poor fellow in the bed is thinking about it. You cannot call in a psychiatrist on all of those cases. I cannot.

All I want to say, then, is that I believe this is the doctor's job. The doctor has to do it and he cannot pass it on to somebody else.

JOHN T. BATE (Louisville, Ky.): In appearing as a co-author I am travelling under false colors as my only claim to authorship is inducing Dr. Trawick to present a paper on post-traumatic psychosis. As the paper developed in the field of post-traumatic neurosis, I do not have any claim to it at all.

I understand that a traumatic neurosis is a defense of the individual to physical threat to his body and it is characterized primarily by withdrawal from the world which is the source of the threat, inhibition of activities and anxiety symptoms. The compensation neurosis is a type of traumatic neurosis in which the secondary gain from compensation plays an important or even major role. The individual is the product of his heredity, his childhood experiences, his reaction to his adult situation and specifically to the traumatic incident.

The localization of pain to the area of trauma is not a symptom of the traumatic neurosis itself. It is more of an hallucination and may seen very severe to the patient. It is due to the intense fixation of the patient on the site of the injury. The desire for the pain is projected onto a part of the body in a similar fashion to the projection of guilt, love or hate onto other persons in paranoia. In the traumatic neurosis of war the compensation payment desired is relief from further danger and return to family and security.

Dr. Trawick has presented two type cases which illustrate these points. I would like to mention one phase of post-traumatic psychosis as illustrated by the case which aroused my interest in this subject:

A forty-eight year old male was admitted with the following injuries: a transverse fracture of the right humerus, a compound fracture of the left femur, junction distal and middle third, a comminuted fracture of the right tibia and partial amputation of the foot, bilateral.

The wounds were débrided and balanced suspension was applied to the humerus and femur, skeletal traction being used in the latter.

After forty-eight hours he had become completely uncooperative and screamed "Charlie" at the top of his voice almost constantly. This continued for three weeks.

Psychiatric consultation at first indicated that the patient had an underlying psychotic state which was made apparent by the intoxication from barbiturates, bromides and chloral through the relaxation of mental controls. But this did not seem to be the whole story and it was not until morphine was given in large and regularly repeated doses without regard to danger of addiction that the individual improved sufficiently to permit definitive surgery. Following this he made steady progress.

This seemed to be the type of case from which we can draw the following conclusions: Some patients who develop a post-traumatic psychosis were really potentially psychotic before and this psychosis becomes apparent when the mental controls are relaxed by shock, pain, drug intoxication or all combined. Heavy doses of morphine will often give sufficient sedation, analgesia and euphoria to permit the mental controls to stabilize the individual partially again.

PHYSIOLOGIC PRINCIPLES UNDERLYING THE TREATMENT OF INJURIES TO THE CHEST*

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THE principal function of the cardiorespiratory system is to supply oxygen to the tissues and to remove carbon dioxide. All therapeutic endeavors in the management of chest trauma are, therefore, directed at the maintenance of this fundamental process. The management and complications of rib fractures, treatment of penetrating and perforating chest wounds and injury of the mediastinum and traumatic hernia of the diaphragm will be discussed. For convenience and completeness it is necessary to segregate the various phases of trauma under somewhat narrow headings. It is important, however, to recall that trauma does not respect anatomic barriers nor does the specialist philosophy confined to one body cavity or region apply to the proper management of injuries in any part of the body. The surgeon who supervises the therapy of trauma must think as a general surgeon. The definite pattern of progression common in some diseases does not apply in traumatic lesions. There are no guiding rules except an understanding of anatomy and perhaps more important, a physiologic approach to all injuries.

The Chest Wall. The normal mechanics of respiration result from the action of the muscles of inspiration. When one unit of muscle ceases to function, the other muscles are usually able to compensate and this response furnishes a factor of safety. For example, even if the outward and upward movement of the thoracic cage is prevented by plaster jacket or adhesive strapping, the diaphragm may carry on the respiratory exchange which will be adequate by increasing the amplitude of this excursion. If the more efficient but dangerous type of chest strapping encircling the entire lower costal margin is employed, restriction of the descent of the diaphragm will follow. In the patient with a dangerously reduced vital capacity this type of immobilization will not be tolerated; moreover, there is considerable difference in individuals and particularly between sexes in the amount of thoracic and diaphragmatic breathing. It follows, therefore, that if chest strapping is to be employed at all it will sometimes be on a trial and error basis and if it is not tolerated, should be abandoned.

Table 1 demonstrates the difference in two normal, healthy males in their tolerance to immobilization of the chest by an encircling strapping at the costal margin and by the often used half strapping at the level of any given rib.

TABLE 1
INFLUENCE OF CHEST STRAPPING ON BREATHING

Cases	Unstrapped		One Strap Encircling Chest		Right Side of Chest Strapped	
	Vital* Capacity	Maximum Breathing†	Vital Capacity	Maximum Breathing	Vital Capacity	Maximum Breathing
Male 195 pounds	5,400	168	4,100	136	4,600	148
Male 200 pounds	5,300	111	4,400	127.5	4,350	117

* Vital capacity in cubic centimeters.
† Maximum breathing in liters per minute.

Unless tremendous destruction of the chest wall has occurred, the effect of this *per se* on oxygen supply is probably in direct proportion to the associated pain which will cause splinting of the thorax and a decrease in respiratory movements.

During the past war numerous excellent accounts became available on the advantages of regional nerve blocking for the control of pain of the chest wall. Even minor contusions of the chest wall may be reflected in the underlying lung by localized atelectasis or hemorrhage; it becomes apparent, therefore, that the best prevention against these complications is relief of pain which in turn will prevent the splinting of the chest wall. The studies of Harmon, Baker and Kornegay[1] have revealed a significant increase in vital capacity following procaine infiltration into fracture sites. The same beneficial effects can be anticipated when paravertebral blocks are employed.

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Hemorrhage. Injuries to the chest may result in hemorrhage from either the systemic vessels or the pulmonary circulatory system. The intercostals and the internal mammary arteries of the chest wall are the most frequent offenders in that locality. A tear in the pulmonary parenchyma may result in blood loss from either a pulmonary artery or pulmonary vein. In the pulmonary system the pressures vary from 20 to 30 mm. of mercury and although hemorrhage from these vessels may be rapidly fatal, bleeding usually ceases because the elastic vessel walls contract into lung tissue. Fatal bleeding is usually avoided except in large, extensive wounds. The subjects of hemorrhage from the chest wall, lungs and complicating hemothorax have been extensively discussed in the literature. It is important, however, to emphasize that the treatment of severe hemorrhage from any part of the body may have a direct and sometimes devastating effect upon pulmonary function by the development of pulmonary edema.

It is probable that the physiologic changes in shock and in acute hemorrhage are similar, particularly as manifested in the lungs. These conditions are characterized by a rapid fall in blood pressure, slowing of circulation, loss of blood volume, anoxia followed by capillary endothelial permeability and tissue edema which finally reflects itself upon the heart and results in death. Experiences during the past war, which have been reported by Beecher[2] and others, have established with certainty the dangers of overloading the circulatory system with blood or plasma in a shocked patient. The same principles apply in cases of acute, severe hemorrhage. Eaton's investigations concerning pulmonary edema have verified these impressions.[3] He reports a predictable pattern of pulmonary moisture within a four-hour period following hemorrhage. He also reports that pulmonary edema may be aggravated by the intravenous use of physiologic sodium chloride, whole blood or plasma and that the effect is twice as severe when sodium chloride alone is administered in the presence of pulmonary moisture. In the experimental animals studied by Eaton, histopathologic lung changes of edema, hemorrhage and congestion were evident as soon as ten to twenty minutes after acute blood loss and were shown to persist for several days.

The lessons learned from war time experience and experimental work along the same lines may not apply to the average injured patient but become of tremendous importance in the poor risk patient, the elderly or in the horribly injured subject. It should not be inferred that the value of transfusions of blood is questioned but it is important that reasonable quantities of blood be given as slowly as possible to these patients and that additional fluid requirements be made up by the subcutaneous route if possible.

Shock. There is no necessity for reviewing the accepted methods of combating shock which apply to all regions of the body. It is, however, important to emphasize that one feature peculiar to thoracic wounds, namely, partial suffocation, may be a factor in producing shock when the lungs are damaged. This may be the result of accumulations of blood or mucus in the trachea or bronchi or may follow hemorrhage or edema in the pulmonary parenchyma. One or both of these factors combined with the anoxemia of shock may be fatal. If respiratory exchange is embarrassed by the accumulation of bronchial secretions or blood clots, successful aspiration through the bronchoscope or by catheter suction may be life-saving. A pulmonary parenchyma drowned with blood or edema fluid constitutes a much more serious problem; oxygen therapy properly applied is probably the most satisfactory form of treatment. It is extremely important, therefore, to consider the possibility of partial suffocation before evaluating a patient's condition and particularly before attempting any major surgical procedure.

During the past war Samson, Burford, Brewer[4] and others described the entity of traumatic wet lung. This condition may be entirely the result of inability to cough up bronchial secretions because of pain and weakness. It has been postulated that reflex bronchial spasm may be involved. The practical applications remain the same; the bronchi must be cleared of secretions and the pain originating chiefly in the chest wall relieved. Final evaluation of the patient's condition must be delayed until these measures have been applied.

Wounds of the Lungs. Either penetrating or non-penetrating wounds of the chest may result in the formation of hemothorax, pneumothorax or both. In this connection it is important to emphasize that early and complete re-expansion of the lung with conservation of

cardiopulmonary function is of prime importance. This principle was successfully applied to thousands of injured men during the war and is equally important in civilian practice.

Air escaping from an injured lung may produce mediastinal and cardiac tamponade. If there is an associated tension pneumothorax, relief of the pneumothorax will usually be sufficient. Advanced subcutaneous emphysema may invade the mediastinum unless it is a rapidly accumulating one resulting from the rupture of a large bronchus. Ordinary instances of subcutaneous emphysema with some mediastinal invasion are usually not serious in nature.

Intrathoracic Pressures. The importance of the maintenance of negative intrapleural pressure in the mechanics of respiration is so well known that no discussion on this point will be included. The absolute necessity for prompt closure of sucking wounds has been understood for many years. It is true, of course, that the larger the opening the more dangerous the consequences but it is also important to remember that immediate reflexion will depend upon the vital capacity of the wounded man. For example, a small opening in the chest wall may be fatal to a patient whose vital capacity has been materially reduced by hemorrhage into the lung or pleura or for some other reason. The principle of the immediate closure of a defect of the chest wall has been substantiated for many years.

Diminished cardiac output and ineffectual oxygenation of the blood will become apparent with any marked intrathoracic pressure change. Bleeding into the pericardium resulting from either contusion or lacerating wounds may produce cardiac tamponade manifested by falling of systemic pressures, diminished pulse pressure and rising venous pressure. As these signs develop, the heart sounds become less audible until finally the phase of the silent heart is reached.

Failure to make the diagnosis of cardiac tamponade often is the result of too much dependence on roentgen examination. The presence or absence of motion in the cardiac silhouette is not recorded on a conventional x-ray film. Only examinations with the fluoroscope or roentgen kymography will establish the excursions of the heart. If one waits until a huge cardiac shadow is apparent, suggesting a collection of fluid, the results may be disastrous.

It is important to remember, however, that pressure relations within the thorax not only effect respiration but effect circulation which in turn will reduce the efficiency of oxygenation of blood. Mediastinal flutter may be associated with an open pneumothorax and all the mediastinal structures may be displaced. Not only the respiratory system but the circulatory system will be effected by torsion of the great vessels, particularly in the right chest by kinking of the vena cava.

The case of a victim of severe thoracic injuries is difficult to evaluate for reasons already described and others. The appearance of a man approaching death may dramatically change to an entirely satisfactory situation following intercostal nerve block and cleaning out of the airways with catheter or bronchoscopic aspirations. Conversely, a false sense of security may be shattered by the development of pulmonary edema, anoxia and death. A completely reliable evaluation of the oxygen saturation of the blood by clinical examination is impossible. Present laboratory methods are somewhat cumbersome but easier procedures for the determination of these data are the subject of considerable attention and certainly will develop.

To insure the greatest safety one must consider the possibility of visceral damage in all cases of thoracic trauma. Each lesion must be evaluated in terms of its effect on oxygen exchange.

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AN ANALYSIS OF THE MANAGEMENT AND COMPLICATIONS OF MULTIPLE (THREE OR MORE) RIB FRACTURES*

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FRACTURE of the rib represents one of the commonest of fractures. It is frequently dismissed as being relatively unimportant; it is overlooked or disregarded when associated injuries are present. As this report will show, fractured ribs are responsible for a formidable list of complications which often occur. Knoepp[1] showed a mortality of 5.9 per cent in patients with multiple fractures and a complication rate of 13 per cent for all rib fractures, single or multiple. Mortality rates as high as 10.4 per cent have been reported.[2]

We have analyzed a series of 109 cases of multiple rib fracture. These are consecutive cases treated by both the orthopedic and the general surgical services. The fracture of a single rib may result in any of the complications which are common in severe chest injuries, and we do not wish to have our exclusion of cases with only one or two rib fractures construed otherwise. But multiple injuries are getting to be the rule and our purpose is better served by considering multiple rib fractures alone.

This information was gathered from a review of the clinical records and x-rays; and when positive statements have been possible, we have made them. Roentgenograms are not the last word in the diagnosis of rib fractures. (Fig. 1.) Many fractures are not easily demonstrated. Also one can seldom afford to rely on one x-ray either for detection of intrathoracic complications or to follow their progress. (Fig. 2.) Physical examination is important but x-rays are essential to intelligent management of chest trauma.

In Table 1 the ages of patients by decades are tabulated. Most cases occur between the fourth and seventh decades inclusive. In the aged the injury is often trivial in nature. The age distribution is explained almost entirely on the brittleness which the ribs achieve since the rib cage must be subject to frequent trauma at any age. Alcohol is an important contributory factor.

Eighty of 109 patients were male. Auto accidents were responsible for injury to sixty-five persons and two-thirds of these were passengers. (Table 11.) Falls accounted for twenty-eight others, fights for four more and three pedestrians were struck by street cars. In a few cases the etiology was unknown. All were admitted to the hospital for an average stay of ten days.

In Figure 3 we have arranged the location and number of ribs fractured. Our patients averaged 5.38 fractured ribs. Fracture of the left ribs is more common and at first we were not inclined to view this as significant; but when a study of stab wounds of the chest revealed the same tendency, we concluded that in some manner most individuals are able to offer more protection to their right side.

The twelfth rib is least likely to be fractured. This is followed by the first, eleventh and then second. The fourth through the tenth are quite exposed and are very frequently injured. This corresponds roughly to the findings of Knoepp,[1] and McCally and Kelly.[3]

The simultaneous occurrence of fracture of the first rib and clavicle on the same side is suggestive of common force applied through the sternum. (Fig. 4.) Approximately one-half of the fractured first ribs were associated with a fractured clavicle on the same side. Horner's syndrome has been noted by others[4,5] but we have no record of its occurrence in these cases. Fractures of the first rib following unusual muscular stresses,[6–8] blow on the sternum,[9] carrying bags over the shoulder[10] and the result of blast,[11] have been reported. It has been considered the rarest of fractures[12] but must take second place to the twelfth rib when multiple ribs are fractured.

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1A 1B

FIG. 1. Two views of fracture of first rib with fracture obscured by superimposed clavicle and second rib in one x-ray. Fracture of ribs is sometimes difficult to diagnose by x-ray.

Associated Injuries. A tabulation of associated injuries to these patients is interesting. (Table III.) It serves to emphasize three points: (1) the severity of injuries suffered by this group of patients, (2) the magnitude of traumatic forces in modern life and (3) the general nature of trauma.

TABLE I
DISTRIBUTION BY AGE

Age by Decade	No. of Cases
0–9	1
10–19	1
20–29	6
30–39	22
40–49	26
50–59	20
60–69	19
70–79	12
Average age	49
Males	80
Females	29

TABLE II
HOW INJURY WAS INCURRED

	No. of Cases
Auto accident (⅔ were passengers)	65
Falls at home or work	28
Fights	4
Hit by street car	3

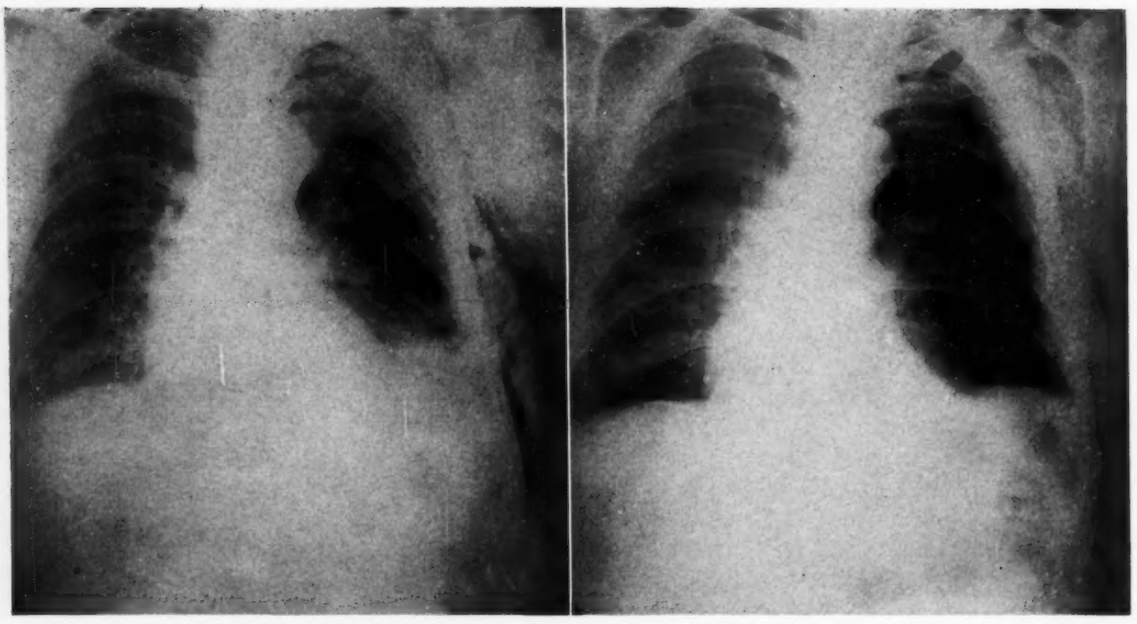
A total of sixty-five patients suffered some injury other than fractured ribs. Included are sixty-one simple fractures of the extremities, spine and pelvis in thirty-six patients, nine compound fractures in eight patients, ten instances of head injury, a few intra-abdominal and kidney injuries, a case of ruptured diaphragm and the inevitable disfiguring lacerations and contusions. All of these injuries were sustained within city limits where the speeds do not compare to those attained on the open highway.

TABLE III
ASSOCIATED INJURIES

	No. of Cases
Simple fractures (in 36 patients)	61
Head injuries	10
Compound fractures (in 8 patients)	9
Intra-abdominal injury	3
Kidney injury	2
Ruptured diaphragm	1

Trauma as a general surgical problem is amply demonstrated. Considerable experience and judgment is required of the surgeon who treats trauma and the obvious is a trap for the unwary. The general surgeon must sometimes consult the surgeon in special fields.

Rupture of the diaphragm is worthy of some comment. It is a relatively uncommon injury which is easily overlooked. The diagnosis, though not difficult, is usually delayed. Barium studies easily disclose a hernia which is almost always on the left. We have recently had occasion to make the diagnosis and carry out



2A 2B

FIG. 2. A and B, serial x-rays of case of multiple fractures of ribs showing progression of a pneumothorax and development of effusion; it would be impossible to detect changes of this nature without x-ray examination.

successful repair. According to a personal communication from the medical examiner, ruptured diaphragm is frequently seen in cases of sudden death but seems rare in those who survive the initial shock of trauma.

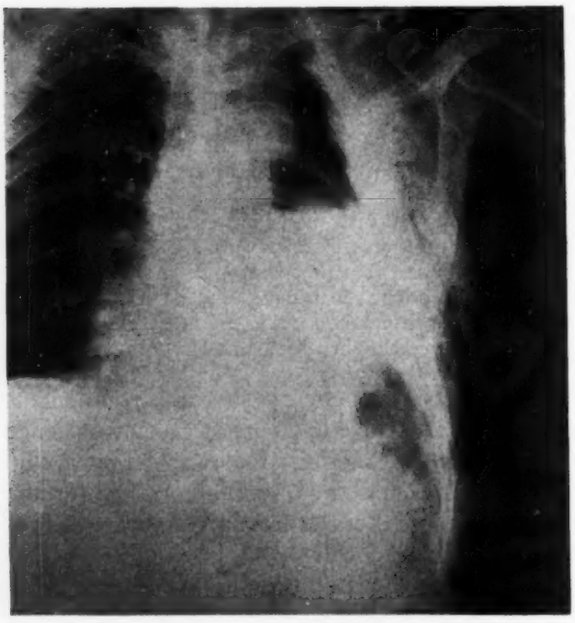


FIG. 2. C, same case as Figure 2A and 2B.

MANAGEMENT OF THE FRACTURES THEMSELVES

Immobilization of rib fractures is not feasible. Any method which achieves immobilization will do more harm than good by restriction of respiratory movement. We have abandoned all forms of strapping and our therapy now consists of reduction of pain by intercostal blocks, observation for complications in hope of preventing their full development and supportive therapy.

However, paradoxical respiration due to flail chest demands rib immobilization. (Fig. 5.) Milder instances may not require fixation but severe forms constitute a threat to life. A number of devices[13] have been utilized to lessen paradoxical excursions. We use a single-pointed cervical tenaculum. This instrument has proven most satisfactory in the common type in which the sternum is the mobile fragment. The instrument can be easily introduced into intercostal spaces and a good grip on the sternum obtained. One or more instruments are introduced and with 5 pounds of traction the excursions are materially lessened. We claim no originality for this method. Doubtless others have devices equal to this in every way. We have encountered one case of chrondritis.

More will be said later about intercostal block but we use this as frequently as necessary to relieve pain. It affords more comfort to the patient when properly performed than any combination of drugs, and often one block will suffice. We avoid drugs which will depress cough

for coughing must be encouraged. Expectorants, steam inhalations and nasal oxygen are useful.

COMPLICATIONS AND SEQUELAE

Only thirty-nine cases, or 35 per cent of this series, escaped without some complication marring their progress. (Table IV.) These patients

TABLE IV
CHIEF COMPLICATIONS OF MULTIPLE RIB FRACTURE

	No. of Cases
Wet lung	39
Hemothorax and pleural fluid	25
Emphysema	28
Pneumothorax	14
Paradoxical respiration	4 (3 deaths)
Ileus	18

comprise a somewhat "lightly" injured group as the average number of ribs fractured was only four, and there were only fifteen complicating injuries as compared to seventy-four complicating injuries in the remaining seventy cases. Any injury in which two-thirds of the sufferers will be subject to a complication is not to be taken lightly.

Wet Lung. This inclusive and descriptive term which many authors have employed[14–17] we have accepted to mean an abnormal accumulation of fluid in the lung. Some synonyms used are traumatic penumonitis, patchy atelectasis, bronchopneumonia, pulmonary congestion and infarction, but a distinction between these terms is impossible. De Takats[18] has experimentally produced it by chest wall trauma, pulmonary embolism and abdominal trauma and considers that wet lung is due to reflex motor and secretory stimulation of the bronchial tree. Thus intercostal block may not only relieve local pain but also break up a reflex arc. In chest injury such as we are considering, blood aspirated material, upper respiratory infections, cardiac failure and unconscious states are contributory factors.

Thirty-nine or 35 per cent of all our patients had wet lung. In this instance clinical evaluation is fully as important as roentgen findings. Clinically a "wet" respiration, ineffectual cough, rales, dyspnea and cyanosis are apt to put in their appearance singly or combined. Cough is shallow and poor in quality. Due to pain, respirations are rapid and shallow and there is often low-grade fever.

Bed rest has only slight effect on the incidence of wet lung. Thirty-two patients had associated injuries which enforced bed rest. The incidence of wet lung in this group was 40 per cent. In seventy-seven cases not confined to bed the incidence was 34 per cent. Visible damage to the underlying lung did increase the incidence. When hemothorax, pneumothorax or emphysema were present, we found that approximately one-half of these cases had

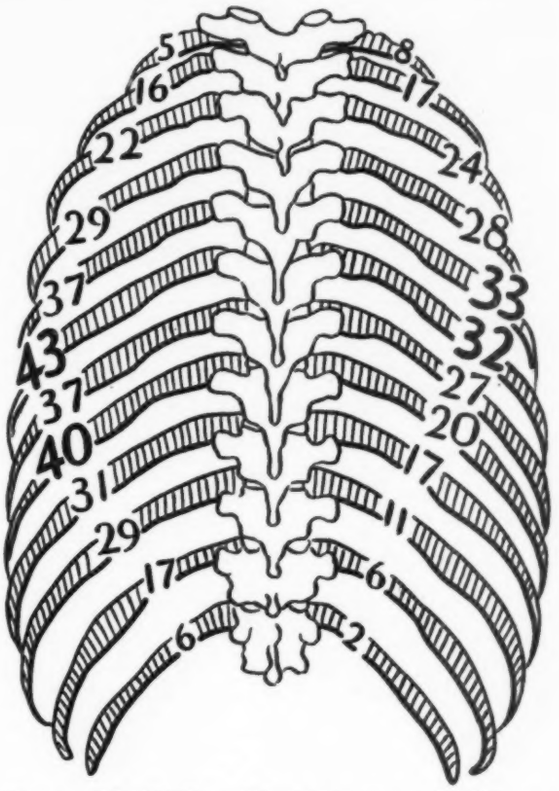


FIG. 3. Distribution of fractures as to rib; for our purpose we have believed that the exact location of the fracture was not significant.

"wet" lung, whereas only one-third of the remainder of the cases had this complication.

We regard "wet" lung as a complication which may have serious implications. It interferes with gaseous exchange as evidenced by cyanosis. We believe it is a predecessor to atelectasis and pneumonia and, in the elderly, it is a significant factor in circulatory failure.

Strapping devices and narcotics which were so widely accepted in the past[19] are out of place in the general treatment of rib fractures. We were interested to find a report of bilateral edema of the legs and ankles following strapping of the chest.[20] This disappeared within twenty-four to forty-eight hours after removal of the tape. This is an extreme case illustrating how great the insult to circulation may be. Strapping does not satisfactorily relieve pain.

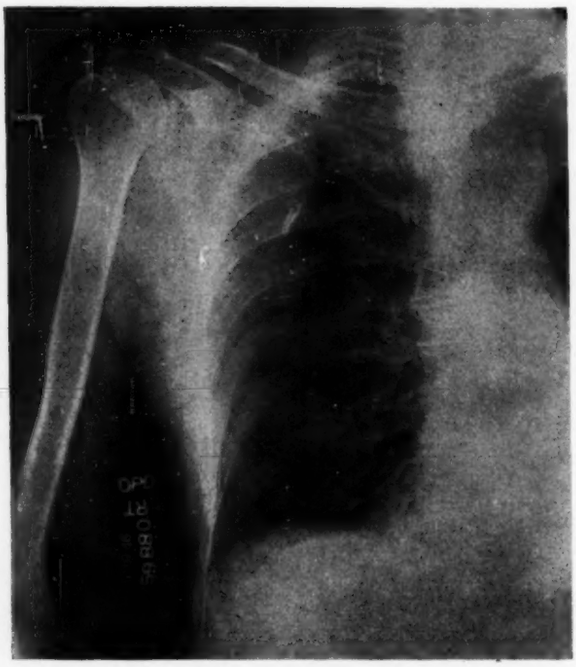


FIG. 4. In this series fractures of the clavicle were present in one-half of the cases of fracture of the first rib. This is probably due to force applied through the sternum.

The patient's chest should be unrestricted and by means of intercostal block which many have advocated[14–17,19–21] he must be made comfortable enough so that he can move about and cough without pain. In this series, however, many were blocked initially and repeatedly and still developed wet lung. We are not sure that the condition can be wholly prevented by any means, but there seems little doubt that intercostal blocks are an important part of the treatment.

Wet lung must be actively and aggressively treated. The patient made comfortable by intercostal blocks must then cough. Patients may have to be cajoled, threatened or assisted, but persistence usually pays dividends. If productive cough cannot be obtained, tracheal aspiration or even bronchoscopy must be employed. Nasal oxygen and penicillin are frequently of value.

Accumulation of Blood and Fluid in the Pleural Space. Twenty-five cases, or 25 per cent of our patients, had blood or fluid in the pleural space. Twelve of these were graded as slight for the fluid only obscured the costophrenic angle. Three patients yielded 1 L. or more of bloody fluid on thoracentesis and were regarded as severe. The ten remaining cases were classified as moderate. The patients with slight hemothorax required no treatment beyond observation. It has been our policy, when significant quantities of blood are present, to remove it as thoroughly as possible by thoracentesis or by water seal drainage. The latter method recommends itself particularly when pneumothorax is also present. In a discussion of hemothorax Melick and Spomer[22] cite many experiments, the oldest being performed on horses as early as 1829 by Trousseau and LeBlanc, to show that respiratory and cardiac movements defibrinate the blood and successive layers of fibrin are deposited on the pleural surfaces. Because of this loss of fibrinogen blood withdrawn from the pleural space will often stay liquid for a long time. In some cases the presence of blood incites exudation from the pleural surfaces and much that is interpreted as continued bleeding is simply increase in the fluid content due to weeping from pleural surfaces. This fluid if tested may have a hemoglobin content considerably below that of blood. The factors which influence successive layering of fibrin are unknown and we are unable to predict in which patients the blood will be absorbed and which will go on to organizing hemothorax. Infection may play a role as almost all patients going on to organization exhibit some fever. When confronted with organized hemothorax decortication remains the only practical recourse.[23] Loculation prevents effective thoracentesis and permanent crippling results if it is left undisturbed. (Fig. 6.)

No patient in this series required decortication. They all represent closed wounds except that small punctures of the lung were present in many of them and we encountered no instances of infection in the pleural space.

All three patients with severe cases were subjected to thoracentesis and in addition five with moderate accumulations were tapped or treated with an intercostal tube. Since we cannot predict the ultimate fate of blood in the pleural space, it is probably better to err slightly on the radical side and perform thoracentesis in borderline cases. (Fig. 7.) Fifteen of these patients also had pneumothorax and/or emphysema and nine patients presented evidence of wet lung.

Emphysema and Pneumothorax. Emphysema is much more common than pneumothorax. The former was present in twenty-eight cases (25.7 per cent) and the latter in fourteen cases (12.8 per cent). It is likely that

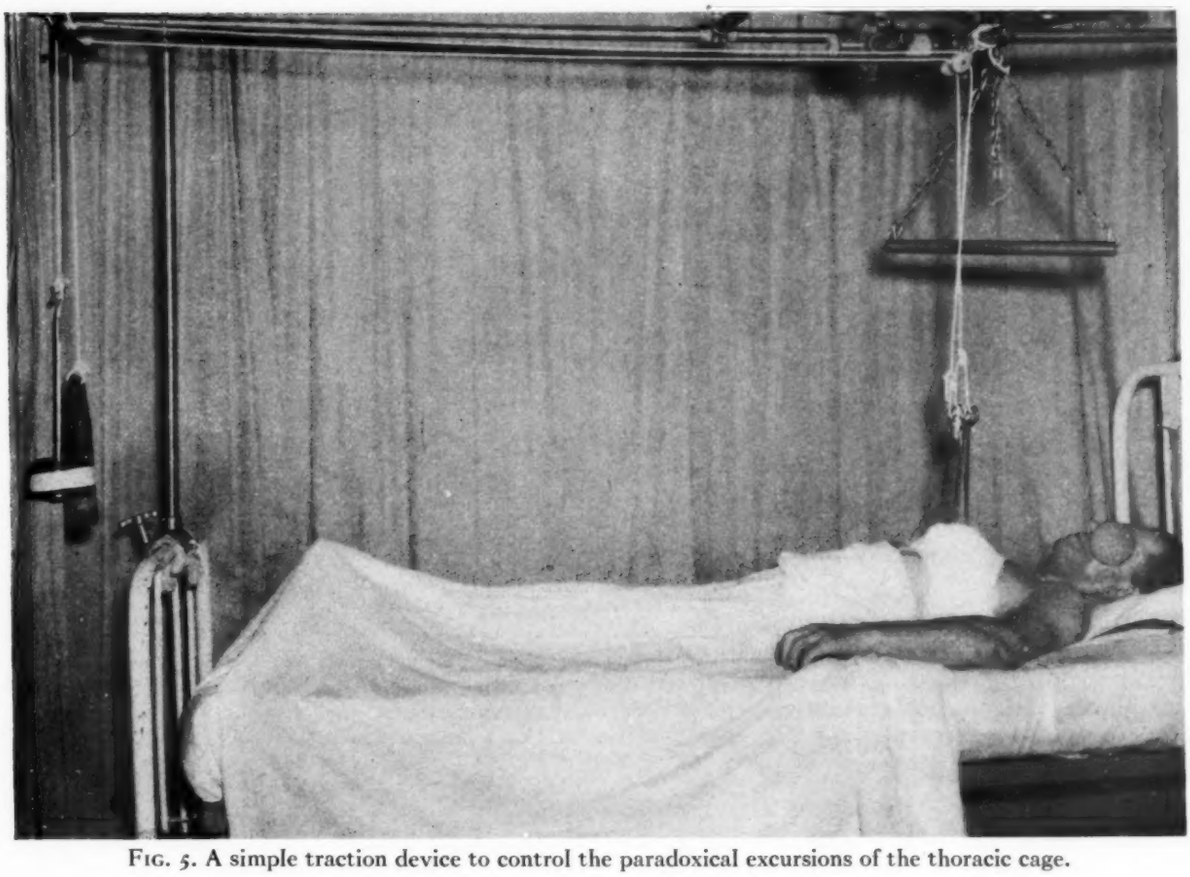


FIG. 5. A simple traction device to control the paradoxical excursions of the thoracic cage.

small amounts of air are unrecognized even in good roentgenograms.

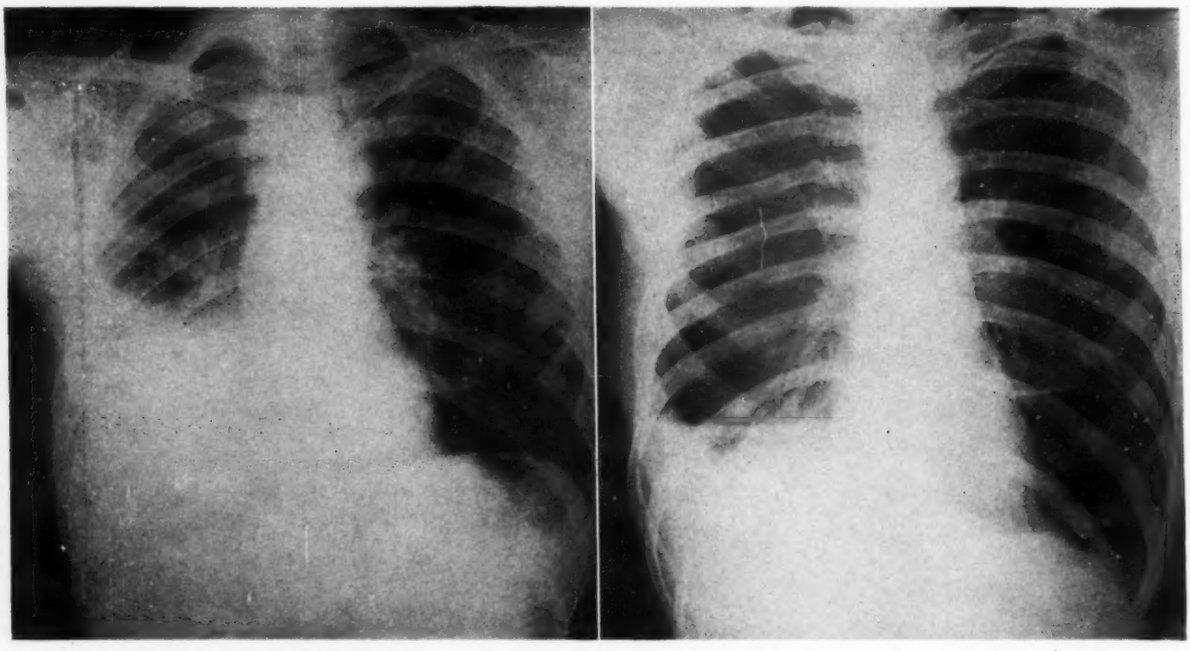
Subcutaneous emphysema is evidence of puncture of the lung. It may occur with rupture of the trachea or esophagus. No cases of this latter type were encountered in this series. Presumably the offending agent is the jagged rib end and the visceral pleural tear must usually be sealed off quickly since so few of these cases are progressive or associated with pneumothorax. Pneumothorax was present in only nine cases.

Emphysema requires very little in the way of treatment even when severe. When associated with pneumothorax we frequently use water seal drainage. Occasionally emphysema is rapidly progressive and may become very extensive. We believe that a small thoracotomy tube will stop this rapid progression even when no "pneumo" is present by induction of a small pneumothorax which pulls the lung away from the rent in the parietal pleura and provides easy exit for air issuing from the damaged lung. We are at a loss to explain why even severe cases of emphysema may exist without pneumothorax unless adhesions are present. Subcutaneous emphysema obscures much detail in x-rays and thus many cases of pneumothorax may be missed.

Pneumothorax requires watchful management. (Fig. 2.) In many instances air will be absorbed but frequently this takes much longer than one would expect. At the same time one must take certain risks in waiting for complete absorption.

In the treatment of pneumothorax we think it is a definite advantage to re-expand the lung and hold it out by means of a water seal drainage apparatus. The complete expansion must be maintained for three to four days. This is less time than would be expended in waiting for the air to absorb. We think it is a mistake to dismiss anyone from hospital observation while pneumothorax of any degree is still present. A little strenuous effort, a hard cough or sneeze or a hiccough may dislodge the material which has plugged the hole and the result may be tragic for the patient.

Some claim that pleural laceration will heal better when the lung is collapsed. We have not



6 7

FIG. 6. This patient shows scoliosis to the affected side; a narrowing of the rib interspaces by x-ray. Following decortication these evidences of captive lung and fibrothorax disappeared.
FIG. 7. From the appearance of this x-ray one would consider this a moderate hemothorax. However, 1,000 cc. of blood were removed by thoracentesis.

observed any delay under our treatment. In fact, apposition to the parietal pleural surface may be advantageous for healing. At any rate, there is no tendency for the lung to recollapse after the water seal drainage has been removed if the lung has been fully expanded for three to four days.

Since all of these cases were closed pneumothoraces, the physiologic upset was not marked and there were no instances of tension pneumothorax. A ball valve lesion in the visceral pleura which allows air to enter the pleural space on inspiration only to be trapped on expiration must be treated at once with a water seal drainage system.

No serious sequelae due to pneumothorax have been encountered in this series. Four of these patients were intubated and six were tapped, and there was no pleural infection.

The only extrathoracic complication of importance is ileus. We have grouped gastric dilitation and intestinal ileus together. Eighteen cases (16.5 per cent) of significant ileus occurred in this series. This is considerably above the incidence reported by Altemeier and Wadsworth.[24] These authors report ten cases in 454 cases of fractured ribs. However, they excluded from consideration cases of pneumothorax, fractured pelvis and fractured vertebrae. They considered ileus to be due to irritation of the splanchnics from direct injury by the fractured ribs or reflexly. The list of associated injuries in our series is fairly imposing. It includes one spine fracture, two skull fractures, eight fractured extremities, two fractured pelves, two kidney injuries and two cases of heart failure. Furthermore, all but one case displayed wet lung or other intrathoracic injury and that case had a fracture of L 2. Thus it can be seen that all these patients were severely injured. Spine fractures, kidney injuries, pelvic fractures and heart failure are all apt to exhibit ileus. Retroperitoneal hemorrhage in the former three instances may play a part.

Whatever the cause, ileus may become extreme and be an appreciable hazard. We have seen great gastric dilatation within a few hours after injury. (Fig. 8.) In this instance a tremendously distended abdomen, grunting respirations, cyanosis and tachycardia were present to a marked degree. A gastric tube brought dramatic relief within a few minutes and it was possible to ascertain the true extent of the patient's injuries. For small bowel ileus we regularly employ a long tube. For large bowel ileus small repeated doses of pitressin are valu-

able. Ileus should never be neglected. To get the best results treatment must be active and direct. We do not believe that drugs have any effect except in instances of large bowel ileus.

DEATHS

Eleven, or 10 per cent of these patients died. (Table v.) Nine patients had severe associated

TABLE V
DEATHS

11 Cases—10%
9 Cases with severe associated injuries
4 cases of primary chest death
Intrathoracic hemorrhage—2
Delayed intrathoracic hemorrhage—2

injuries. It was difficult to evaluate the role chest injury played in their deaths but, even when death was not due to chest injury, it was always decisively contributory.

In those patients in whom chest injury played a decisive rôle, delayed hemorrhage was responsible in three. As an example: M. W., a sixty year old colored female was struck by a car, suffering fractures of the left first to eighth ribs inclusive, the right second rib, the pelvis and the left clavicle. Despite many intercostal blocks she developed wet lung and was bronchoscoped. She developed rather marked emphysema and ran a low fever for three days. However, her condition was improving when she suddenly died on the fifth day. An autopsy at the coroner's office revealed intrapleural hemorrhage. No other explanation was offered for her sudden death.

The softening of fibrin clots, respiratory movements, infection and contusion to vascular walls with subsequent necrosis might all enter into such a termination.

We are sure that chest injury played an important contributory role in several other deaths. We are convinced that wet lung, especially, is an important factor particularly in the elderly patient whose circulation is not too robust and whose pulmonary reserve is low.

SUMMARY

1. One hundred nine cases are presented in which each patient had three or more fractured ribs.

2. The cases are predominantly males in the fourth and seventh decades.

3. There seems to be a definite tendency for fractures to be more frequent on the left.

4. Both the shortcomings of x-rays and the necessity of obtaining serial x-rays are stressed.

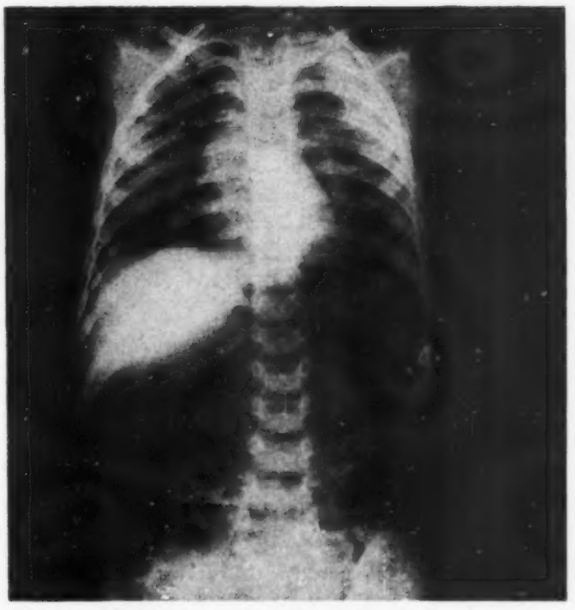


FIG. 8. Marked gastric dilatation following chest trauma; this picture was taken two hours after injury. A Levin tube passed into the stomach immediately and remarkably relieves these patients.

5. The coincidence of fractured first rib and clavicle on the same side is discussed.

6. These patients presented an imposing array of associated injuries which serves to emphasize that trauma is a general surgical problem and that a thorough, systematic examination is necessary. Ruptured diaphragm is discussed.

7. Our general program for treatment of fractured ribs is presented, emphasizing the importance of intercostal block and avoidance of restrictive dressings and cough depressants.

8. The fixation of the "stove in" chest is discussed.

9. Intrathoracic complications may be anticipated in two-thirds of all cases of multiple rib fracture.

10. The causes and treatment of wet lung are discussed at some length.

11. The incidence, treatment and sequelae of hemothorax, pneumothorax and emphysema are discussed. It is important to remove blood completely from the pleural space and to institute prompt measures for the re-expansion of collapsed lung.

12. This series had a 10 per cent mortality. Delayed hemorrhage is a definite hazard and wet lung is an important contributory cause.

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TREATMENT OF PENETRATING AND PERFORATING CHEST WOUNDS*

A DISCUSSION OF ITS COMPLICATION, THE ORGANIZED HEMOTHORAX

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THE penetrating or perforating chest wound is by its very nature a wound of violence. Nowhere but under the conditions of warfare can this type of wound be studied and treated in truly significant numbers. This lesion as it occurs in civilian life is closely related to its counterpart inflicted in armed combat. Therefore, the principles evolved from the observation and treatment of a large group of these wounds should be applicable to their management in civilian life.

The statistics herein presented and the suggested modes of treatment result from the experience[1] of a group of surgical teams operating in the European theater during the recent war.

Chest injury mortality has been reduced from approximately 25 per cent in World War I to about 6 per cent in the last conflict. This improvement results in great part from a better understanding of respiratory physiology and the application of this knowledge to actual treatment. Obviously, improved anesthetic technics and chemotherapeutic advances played an important role in these encouraging figures.

PRINCIPLES OF TREATMENT

Much assistance in guiding treatment of the chest casualty can be gained by an accurate estimate of the course of the wounding missile. The amount of damage and the organs involved may be indicated by such knowledge. In the case of a retained missile anteroposterior and lateral x-rays of both chest and abdomen will enable the operator to plot the probable wound tract and to compute the organs involved. The value of two-position views (anteroposterior and lateral) cannot be overemphasized in the diagnostic process of accurate wound appraisal. The course of a perforating wound can be estimated by lining up the wound of entry with the wound of exit when proper allowance is made for position of the wounded subject at the time of injury. By virtue of these studies involvement of the mediastinum or diaphragm may be indicated taking the case out of the simple chest wound category.

Contrary to the situation in the abdominal wound when importance is attached to the interval between injury and operation, the significant period in the chest wound is that required to stabilize cardiorespiratory function and relieve anoxia.

The establishment of an adequate airway is of prime importance in emergency treatment of the chest wound casualty. Normal respiratory exchange must be instituted both for the purpose of relieving anoxia and also for the proper preparation of the patient for operation if the latter is indicated. Anoxia, which may be the result of an obstructed airway, wet lung, depressed cough reflex due to pain, etc., may contribute measurably to the picture of shock which these patients frequently show. Diminished blood volume will contribute in varying degrees to the shock state in which many of these patients are found. However, in other patients with minimal blood loss although apparently in severe shock, marked improvement may be obtained by correcting the conditions causing anoxia.

The sucking chest wound indicates a connection between the pleural cavity and the external atmosphere. Early establishment of an intact thoracic cage is a basic necessity in restoring normal respiratory physiology. Emergency treatment can be accomplished by a simple occlusive dressing to be followed later by indicated surgical repair.

Hemoptysis is an indication of pulmonary parenchymal damage. It accompanies the majority of chest wounds. The presence of blood in the tracheobronchial tree contributes to the obstructive factors preventing normal

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aeration. Its early removal, either voluntarily by the patient's efforts or mechanically with the operator's assistance, is to be encouraged.

Oxygen administration as a supportive measure is a valuable adjunct in assisting the patient with a chest wound over periods of difficult aeration. It is not stressed purposely in this article in order to emphasize the more basic principles of re-establishment of normal pulmonary function.

In summary the surgeon will achieve the best results in a chest casualty by attempting to establish normal respiratory exchange with an unobstructed airway in a patient with fully expanded lungs and an intact thoracic wall. Blood replacement, but not overloading of the cardiovascular system, is indicated when there is assurance that the shock state is not entirely due to anoxia.

PRACTICAL APPLICATION OF THESE PRINCIPLES

Evaluation of Damage Inflicted. History, physical and roentgen examination will accord the examiner a means of estimating the amount of injury present in the chest wound casualty. Any suspicion of mediastinal or diaphragmatic involvement calls for additional investigation and therapy from this point onward. The presence of a retained foreign body at this point is of no concern unless it is of an unusual size or nature.

Aspiration of the Chest. The presence of blood and air in the penetrated chest cavity is a common finding in chest injury. Blood and air occupy space previously reserved for the functioning lung. The early and complete removal of blood and air is a prerequisite to re-establishment of a fully expanded, functioning lung. This can be accomplished by repeated and thorough thoracentesis. Considerable objection has been raised in the past to the re-expansion of the freshly wounded lung by aspiration of air or blood. It has been stated that re-expansion of the wounded lung will incite fresh bleeding or that pneumothorax is valuable in preventing continued hemorrhage. We have not found this to be so. It was the common experience of many members of this group to examine many extensively lacerated lungs in the course of operative procedures from two to twenty-four hours after initial injury. It was unusual to observe hemorrhage or oozing of note in this lacerated tissue. Major hemorrhage that continued or was re-initiated arose from systemic vessels such as the internal mammaries or the intercostals and required active intervention for control. It was also our impression that patients with injuries to the major pulmonary vessels rarely if ever survived long enough to reach centers for definitive treatment.

In addition to regained pulmonary function the re-expanded lung tends to prevent the establishment of a massive pleural infection should contamination be overwhelming. Thus if infection should complicate the situation, the surgeon would be faced most probably with a small basal empyema; whereas if expansion were incomplete, he would have to deal with a total empyema.

Failure to establish complete re-expansion by repeated and thorough thoracentesis also carries the threat of a chronically collapsed and imprisoned lung. This condition condemns the patient to impaired respiratory reserve and the prospect of a second major pulmonary operation.

Intercostal Nerve Block. This is a frequently described[2–4] and simply performed procedure which is of paramount importance in treating the chest wound patient and also in preparing him for indicated operations. Severe chest pain is a frequent complaint of patients suffering penetrating or perforating wounds of the chest. This pain is contributory not only to the shock state but also tends to suppress the voluntary cough reflex on which the patient relies to rid his tracheobronchial tree of impeding substances. Relief of chest pain by intercostal block is an important factor in breaking up the cycle described as wet lung.[5] This procedure is more efficient in the relief of chest pain than the administration of morphine which must be given with restraint in chest injuries. For intercostal block to be most effective it must be performed at least two levels above and below the area of injury. There is no contraindication to repeating intercostal blocks should it be required for control of pain.

Tracheobronchial Aspiration. A large amount of the products of injury to the lung parenchyma find their way into the tracheobronchial tree. All tend to accumulate in the tracheobronchial tree of an injured lung. The condition is cumulative and with the patient's inability to eject these substances, voluntarily normal air exchange is blocked. This condition can be corrected in two ways. A suction

catheter can be introduced into the trachea in a manner previously described.[6,7] The apparatus required is simple and usually available. The presence of a catheter between the vocal cords and in the area of carina is of itself sufficiently stimulating to initiate a cough reflex. Suction will remove much of the obstructing débris and help to re-establish normally functioning lung tissue. This procedure may be repeated at frequent intervals with beneficial effect. In the hands of a trained operator bronchoscopy will accomplish the same effect to a greater degree. The secondary dilating effect of bronchoscopy on the tracheobronchial tree is of further assistance in correcting this condition. Bronchoscopy may also be repeated as required.

TABLE I
COMPARATIVE REPLACEMENT THERAPY
(ABDOMINAL VS. THORACIC WOUNDS)

Cases	Average Amount of Blood Per Case	Average Amount of Plasma Per Case
907 Abdominal wounds	2,382 cc.	888 cc.
1,119 Thoracic wounds	1,160 cc.	640 cc.

Fluid Replacement. Unless major blood loss is immediately obvious, a much better evaluation of blood replacement in a thoracic casualty can be made after cardiorespiratory balance has been attained by the emergency measures already outlined. Overloading of the circulatory system is easily accomplished in the chest case by overzealous blood or fluid replacement. The traumatized lung, which is frequently compressed by an accompanying hemopheumothorax, is a crippled organ which will respond poorly to an increased work load. Table I shows comparative replacement figures in thoracic and abdominal casualties.

The rate of replacement is equally important and should never be rapid except in cases of obvious major blood loss or continued blood loss. Plasma and other fluids play a less important role in replacement therapy and probably should be reserved for later use in the correction of a contorted blood picture. It may be predicted that the problem of fluid replacement will require more careful judgment in administration for civilian casualties since the frequency of cardiac and pulmonary complications will be higher in that group.

Indications for Thoracotomy. While the average penetrating or perforating wound of the chest can be handled by conservative surgical measures, there are certain indications for thoracotomy. These indications are definite and limited. Table II records the number of thoracotomies performed in a group of about 1,200 chest casualties. The indications warranting thoracotomy are listed.

TABLE II
OPERATIVE PROCEDURES

	Cases	Mortality Rate, Per cent
Chest wall only	768	6.9
Thoracotomies	435	12.4

RECORDED INDICATIONS FOR THORACOTOMY

Traumatic	156
? of thoraco-abdominal wound	122
? of persistent bleeding	36
Injury to mediastinum	20
Foreign body	11
Lung laceration	3
Bone fragments	3
Bronchial fistula	3
? of esophageal wound	3

The greatest number of cases is listed under the heading, "Traumatic Thoracotomy." In these instances the operative procedure was actually forced on the surgeon by virtue of the size of the wound. Here the size of the wound will permit evaluation of parenchymal damage, thorough policing of the pleural cavity and removal of easily accessible foreign bodies in little more time than is required to reconstruct the chest wall and establish an intact pleural space. The traumatic thoracotomy will not be seen commonly in civilian life since the majority of these casualties were the result of wounding by high explosive shell fragments. If injury to mediastinal structures or perforation of the diaphragm cannot be diagnosed by ordinary measures, thoracotomy is mandatory. An untreated perforation of the esophagus or stomach will certainly increase the morbidity if not the mortality of these casualties.

Continued bleeding from systemic vessels required further and careful investigation. Among the most common sources of continued

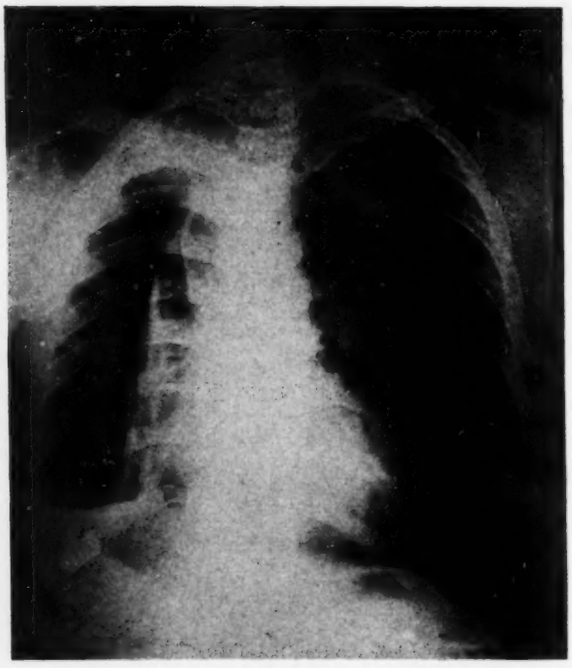


FIG. 1. Typical x-ray of organized hemothorax following penetrating wound of chest; shell fragment at base of right pleural cavity. Note compressed and imprisoned right lung; narrowed intercostal spaces and flattened chest cage on right.

hemorrhage were injured intercostal and internal mammary vessels.

Foreign bodies, lung lacerations or bone fragments are not in themselves indications for thoracotomy in the primary definitive treatment of the chest casualty. Foreign bodies, unless of unusual size or composition, may be removed at a later date under more auspicious circumstances. Laceration of the lung is an inevitable complication of almost every penetrating or perforating chest wound. This lesion alone does not call for operative interference. The ability of damaged lung parenchyma to repair itself without complication was frequently noted by observers in this group.

Typically, small peripheral bronchial fistulas will manifest a tendency to spontaneous closure providing that a re-expanded lung can be kept in close contact with the chest wall. Larger defects in the major bronchial branches will require operative repair.

Pressure Pneumothorax and Subcutaneous Emphysema. Pressure pneumothorax occurred in surprisingly few instances in this collection of cases. When present it is a serious threat to respiratory stability and requires immediate correction. This condition results from a ball-valve type of action in the chest wall or in a traumatized bronchus. With each successive phase of inspiration there is an increase in intrapleural pressure. Eventually severe mediastinal shift occurs with marked respiratory and circulatory embarrassment.

This serious complication may be diagnosed rapidly and simply by physical signs, the most prominent being the easily palpable tracheal shift away from the wounded side.

TABLE III*

Anesthetic Agents	Cases
Ether	307
Pentothal	108
Gas-oxy-ether	673
Novocain	121
Type of Inhalation	
Endotracheal	862
Open	56
Mask	33

*Tables I, II and III, slightly modified, have been taken from "Forward Surgery of the Severely Wounded."[1]

The immediate danger can be forestalled by relieving built-up pressure in the affected chest through the use of a needle connected to a water-seal trap. This was accomplished often in the field by inserting an intravenous-type needle in the second interspace and connecting the needle to a container of water below the patient's body level by plasma tubing. This simple plan is effective until the underlying defect can be corrected.

Subcutaneous emphysema is seen quite commonly in chest wounds. Its most frequent source is the punctured pleural surface. Of more serious import is the emphysema resulting from esophageal perforation and tracheal or major bronchial injury.

These subcutaneous extravasations of air subside rapidly after the underlying pathologic disorder is repaired and carry no special significance other than diagnostic.

Anesthesia. The most common type of anesthesia used was gas-oxygen-ether administered by the endotracheal route as outlined in Table III. Contemplated or probable invasion of the pleural cavity during an operative procedure demands pressure-controlled anesthesia administered by a competent anesthetist. The use of pentothal or local anesthetics should be entirely reserved for those cases in which there will be no question of entering the pleural cavity.

THE ORGANIZED HEMOTHORAX

Among the postoperative problems to be dealt with in the chest casualty is the com-

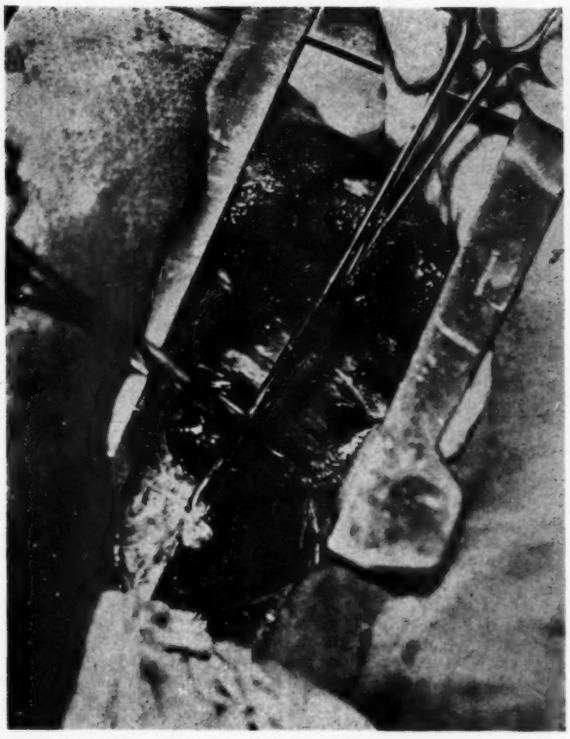


FIG. 2. Thoracotomy for decortication; fibrous encapsulating membrane of partially decorticated lung held in Allis clamps; underlying normal, shiny pleural surface of lung below crossed clamps.

plication of organized hemothorax. The lesion is characterized by an immobile, unexpanded lung which is held captive by a thick, connective tissue membrane extending over all available visceral and parietal pleural surfaces. Usually varying amounts of old blood products are present as well as an unorganized clot and a shaggy detritus which is the result of reactive exudation and old hemorrhage. A typical x-ray of this condition is shown in Figure 1. The exudate may be infected or it may be sterile.

The obvious treatment of this complication is the prevention of its occurrence by the application of the principles already outlined for management of the original chest wound. Unfortunately, under conditions of warfare the continued active treatment of the original chest casualty was prohibited in many cases by unusual circumstances. Under civilian conditions there should be little difficulty in maintaining a completely expanded lung and a thoroughly policed pleural cavity. It is conceivable that small residual empyemas would not be unknown under these conditions but the occurrence of organized hemothorax should not be a major problem.

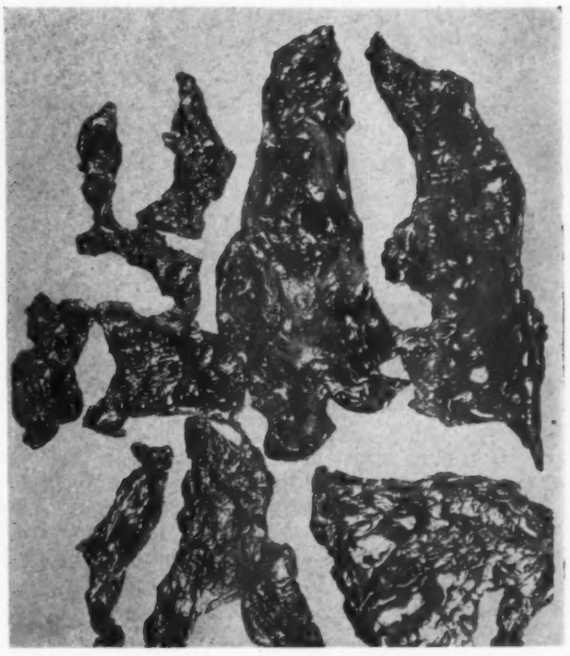


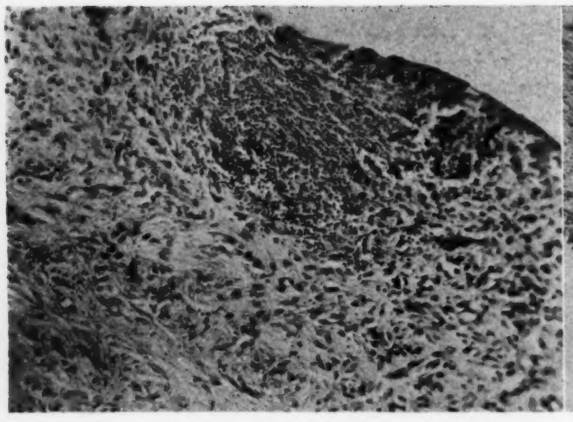
FIG. 3. Gross specimen of excised fibrous peel removed from visceral pleural surface.

The establishment of an organized hemothorax of major degree leaves the patient with diminished pulmonary parenchymal function. In addition gradual immobilization of the chest wall on the affected side increased respiratory disability.

Decortication, the operation by which the encapsulating membrane or peel is removed from the pleural surface of the lung to permit its reexpansion, is not a new procedure.[8,9] It has been utilized most frequently since the end of the last century in assisting the obliteration of old, chronic empyema cavities. It has been re-employed during and since the late war by many operators[10–13] for the correction of this lesion and related conditions.

Actually there is some question concerning the functional value of decorticated lung following varying periods of imprisonment. Investigation of this problem is now in progress.

The operation of decortication is performed most profitably three to six weeks following the original injury. It is during this period that the investing membrane is sufficiently organized to allow easy peeling but at the same time is not too adherent to cause injury to the underlying lung during the process of removal. The most important areas requiring careful removal of the imprisoning membrane are the peripheries of the imprisoned lung when it is contiguous with the chest wall, the fissures and



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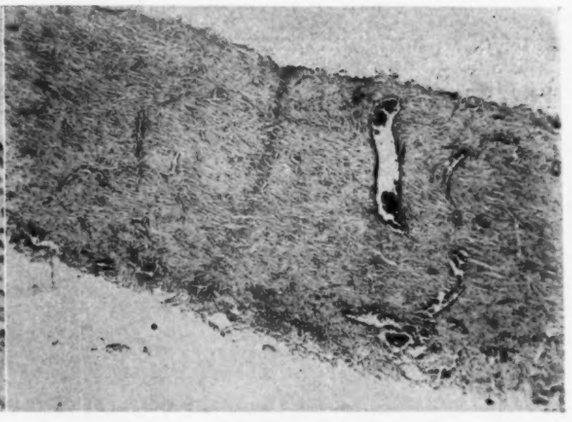

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FIG. 4. High power microscopic cross-section of fibrous peel; upper right field shows early phase of organization with old blood, fibrin and cell detritus. In the periphery of this area there is fibroblastic invasion; remainder of field is occupied by organized fibrous connective tissue. (× 100.)

FIG. 5. Low power microscopic cross-section of the fibrous peel showing well developed blood vessels running generally at right angles to the connective tissue stroma; lower portion of field shows early organization and is apposed to the visceral pleural surface. Upper portion of field is adult connective tissue and lines the pleural space. (× 8.)

the diaphragmatic surfaces. Small central areas of this investing membrane may be found to be so intimately attached to the pleural surface that they defy safe removal. Areas of this type

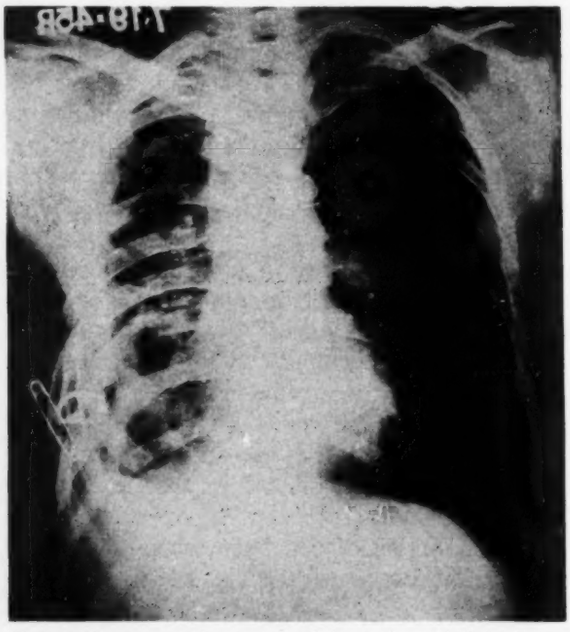

FIG. 6. Postoperative x-ray of decorticated right lung. (Figure 1 is preoperative x-ray.) Tube in ninth right interspace to drain small residual empyema; right lung reexpanded and shell fragment removed.

when not removed have not impeded full reexpansion of the lung.

Removal of this membrane or peel leaves behind it a normal-appearing, shiny and expansible pleural surface. (Fig. 2.)

The membrane is composed of fibrous connective tissue (Fig. 3) which results from reaction of the pleura to the retained blood products. Organization of these products takes place with vascularity being supplied by the underlying pleura. High and low power microscopic sections typical of this membrane are shown in Figures 4 and 5.

The presence of infection hastens the process of organization of this membrane. Infection does not contraindicate the operation of decortication. Quite frequently a low grade infection is present but the procedure may be carried out with little fear of serious complication, particularly with the assistance of antibiotic protection. Small basal empyemas may occur but can be handled effectively by simple drainage. Figure 6 shows a typical patient postoperatively who had decortication, with drainage tube at the base.

Occasionally we have used the intercostal tube in the later postoperative period as an open form of drainage to complete evacuation of an obviously infected residual space.

It is interesting to note that the markedly thickened membrane or peel which is also present on the parietal surface of the pleural cavity does not require removal. The removal of this portion of the membrane is difficult to accomplish and unnecessary as shown by follow-up x-rays of these patients. With full

expansion of the lung and the return of normal respiratory exchange, the markedly thickened parietal membrane thins out and within a period of six to twelve months can scarcely be demonstrated in the chest film.

The institution of remedial breathing exercises early in the postoperative period of the decorticated patient is of extreme value in re-establishing normal thoracic function. The value of these exercises has been amply demonstrated by Edwards and Harken.[14] They serve not only to correct thoracic cage deformities but aid in re-expanding and maintaining re-expansion of the released lung.

SUMMARY

1. There has been a marked improvement in the treatment of the acute chest wound based on a better understanding of respiratory physiology.

2. Although the principles of treatment and their application are based on experience gained under conditions of warfare, it is believed that they can be applied profitably to the civilian casualty.

3. The importance of establishing stable respiratory function before operation is pointed out. The methods at hand for accomplishing this stabilization are described.

4. The implications of fluid replacement therapy in the chest casualty are discussed.

5. The indications for thoracotomy in wounds of the chest are presented.

6. The complication of organized hemothorax is discussed and its treatment described.

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INJURIES TO THE MEDIASTINUM*

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MEDIASTINAL structures may be injured by penetrating instruments or projectiles, non-penetrating crushing violence, or in the case of the trachea and esophagus by objects introduced through these passageways. The structures which are of traumatic surgical interest are the heart and great vessels in the anterior and superior mediastinum and the trachea, bronchi, esophagus and descending aorta in the posterior mediastinum.

Penetrating wounds of the heart and pericardium were covered by Maguire and Griswold at the 1947 meeting of The American Association for the Surgery of Trauma. In civilian practice the most important weapons are in order, the knife, pistol and ice pick. In military practice low velocity shell fragments were the most common cause of injury to patients admitted to hospitals since injury by high velocity projectiles is likely to result in immediate death. Penetrating wounds of the heart and great vessels may manifest themselves by (1) tamponade or (2) hemorrhage externally or into the thoracic cavities. Tamponade due to accumulation of blood under pressure within the pericardial cavity presents Beck's triad of acute cardiac compression. This triad consists of (1) falling arterial pressure, (2) rising venous pressure and (3) a small quiet heart. If a large rent in the pericardium allows decompression of the hemorrhage into the pleural cavities or if the wound involves extrapericardial portions of the great vessels, the symptoms and signs are those of internal thoracic hemorrhage. In either case early emergency surgery is imperative except in the small group of patients with slowly developing tamponade which may be relieved by aspiration as suggested by Bigger and Blalock.

The surgical approach depends upon the location of the wound and the suspected internal lesion. Left anterior approach to the heart suffices in most cases and is carried out through a transverse incision with division or resection of one or more costal cartilages and a portion of the sternum if necessary. Occasionally a right-sided or even a posterior approach to the heart may be indicated due to the location of the wound. The great vessels in the upper mediastinum may be approached by resection of the inner ends of the clavicle and appropriate portions of the upper ribs and sternum or by an upper sternal-splitting incision. Approach to the descending aorta is best made by a wide left transthoracic exploratory incision.

The pericardium is opened widely to expose the heart. The placement of a traction suture in the apex as advocated by Beck is of the utmost importance in controlling the heart during suture. Additional traction sutures may be used to rotate the heart for better exposure of the wound. Care must be taken in dislocating the heart, however, because of interference with cardiac function. Fine silk on small curved needles is the suture material of choice for wounds of the ventricle as well as the auricles. Due to thinness of the auricular wall and bleeding from the needle holes, gelfoam is a useful adjunct to suture in all wounds of the auricles and some wounds of the ventricles. As in all cardiac operations drainage is important to prevent postoperative tamponade. This is best accomplished by a wide opening between the pericardium and the pleural cavity to avoid the hazards of infection from external drainage.

Contusion of the heart was first emphasized by Beck and is probably of more frequent occurrence than is generally realized. In civilian life the most frequent cause of contusion is a blow on the anterior surface of the chest as from the steering wheel in an automobile accident, but contusion may also be caused by weapons or projectiles which penetrate the thoracic wall and bruise the heart. Samson found twenty-six cardiac contusions in wounds of the chest which were opened for other reasons. There was a 40 per cent cardiac mortality in his patients. Recognition of cardiac contusion from non-penetrating injuries may be difficult. The outstanding physical finding is a peculiar "tick-tock" heart sound and the

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finding of electrocardiographic abnormalities simulating coronary occlusion. Electrocardiograms should be taken in all cases of non-penetrating injury to the anterior thoracic wall. The treatment of cardiac contusion is similar to that of coronary thrombosis, that is, rest of the cardiac muscle until healing has occurred. Patching of the contusion with fascia lata or other material has been suggested by Beck.

Retained foreign bodies in the heart are rare in civilian practice. That such retained missiles are not uncommon in military life is shown by the excellent reports of Harken of 134 patients from whom missiles were removed from the great vessels, heart and pericardium. According to Harken such foreign bodies should be removed to (1) prevent embolism, (2) reduce the danger of bacterial endocarditis, (3) prevent recurrent pericardial effusion and (4) diminish incidence of myocardial rupture or hernia. In his hands the removal of such foreign bodies was a safe procedure and certainly should be carried out unless the foreign body is of minute size.

Injuries to the Trachea and Bronchi. Injuries of the trachea and bronchi may occur from penetrating and non-penetrating violence. They manifest themselves by hemorrhage into the trachea and by emphysema of the mediastinum which later spreads to the subcutaneous tissues. The air which escapes from the ruptured trachea or bronchus infiltrates the mediastinum, rises upward into the neck and becomes subcutaneous and may spread over the trunk as far as the lower extremities. This emphysema while extremely uncomfortable is rarely dangerous. It may be relieved by a low collar incision with blunt dissection into the anterosuperior mediastinum to allow escape of air. The trachea should be kept clear of blood by bronchoscopic aspiration. Recovery is the rule unless there are associated fatal injuries. A late complication of rupture of the bronchus may be stenosis and resulting atelectasis which may require pneumonectomy or lobectomy.

Injuries to the Esophagus. The esophagus may be ruptured by (1) external violence by missiles or projectiles, (2) internal violence by swallowed foreign objects or instrumentation or (3) spontaneous rupture from forceful vomiting, particularly in alcoholic subjects. Up until a few years ago this condition was almost uniformly fatal because of the ensuing septic mediastinitis. Proper use of sulfonamides and antibiotics has changed this picture along with a more aggressive surgical attack upon these injuries so that the prognosis today is fairly good. Primary suture of the laceration, with drainage of the surrounding mediastinum, is the method of choice in the early case but is seldom carried out because of delay in making the diagnosis before mediastinitis has occurred. At this stage x-ray examination will usually show widening of the mediastinal shadow and air in the periesophageal tissues. Barium studies should not be used as a diagnostic procedure. The proper treatment is withholding all food and fluids by mouth, administration of large doses of antibiotics and adequate exposure of the site of rupture by mediastinotomy with adequate suction drainage. In some cases, particularly those due to a missile or a weapon which injures the esophagus and trachea, there may be a resulting tracheo-esophageal fistula which may be closed after the infection is under control and healing is under way. If there is a communication with either pleural cavity, empyema will of course be a complication.

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TRAUMATIC HERNIA OF THE DIAPHRAGM WITH STRANGULATION AND GANGRENE OF THE STOMACH*

REPORT OF TWO CASES

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MASS gangrene or acute localized ischemic necrosis of a stomach that has herniated through the diaphragm is apparently a very rare condition. Stuart Harrington[1,2] with a personal series of over 430 cases of diaphragmatic hernia recalls about six perforations of pressure ulcers in herniated stomachs but no case of gangrene of this viscus. Nor do the reports of other authorities in this field[3–7] mention specific instances of gangrene. In a cursory survey of English and American literature, including the excellent review by Carter and Giuseffi,[8] we discovered only five cases, including our own, of mass or localized gangrene of the stomach.[9,10] The explanation for this is probably the unusually rich gastric blood supply and muscularity. In contradistinction, the colon and small bowel are much more susceptible to strangulation and reports of gangrene of these viscera are not too uncommon.

CASE REPORTS

CASE 1. L. H., a colored male laborer, aged thirty-seven, was admitted to Nichols Veterans Administration Hospital on April 10, 1948, with stab wounds in the epigastrium and in the left posterior chest in the seventh interspace, 4 cm. from the spine. Exploratory laparotomy at this time revealed only a small laceration of the left lobe of the liver. Admission chest x-ray showed no evidence of diaphragmatic hernia.

Following surgery the patient was remarkably free of pain and did not vomit but complained of shortness of breath. Physical signs and x-ray findings seemed to indicate a left hemothorax which reached the second left interspace. Daily thoracenteses withdrew 250 to 575 cc. of bloody fluid. Five days after admission the fluid became darker and had a foul odor; culture revealed anaerobic, hemolytic streptococci, Staphylococcus aureus, B. coli and B. aerogenes. X-ray now revealed an extensive area of density in the left thorax but in its center was a clear area with a fluid level. (Fig. 1.) The significance of this was missed at the time. The patient was spiking a temperature of 101.5° to 102.0°F. in spite of intrapleural and intermuscular penicillin.

On April 17, with a preoperative diagnosis of infected hemothorax, a left thoracotomy was carried out through the bed of the resected seventh rib. It was found that the stomach fundus had herniated through a 2½ cm. laceration in the posterolateral aspect of the diaphragm about 3 cm. from the esophageal hiatus. This protruded portion was black and gangrenous but intact and there was no obstruction of the stomach. The diaphragmatic defect was enlarged a few centimeters to allow delivery into the chest of the spleen and stomach well past the gangrenous area. The necrotic wall was excised and the stomach was closed. The stomach and spleen were then returned to the abdomen and the diaphragmatic defect was repaired. The layer of organizing blood clot and fibrin imprisoning the collapsed left lung was removed, allowing its full re-expansion. The chest was then closed around a catheter for suction drainage.

The patient had a protracted convalescence complicated by a gastric fistula through the thoracotomy wound but he did not develop peritonitis or appreciable empyema. On May 12th a small intrapleural abscess was excised and the fistula was closed. The patient was discharged from the hospital August 24, 1948. He returned to work about October, 1948, and when last contacted on May 6, 1949, he was in good health and free of complaints.

The features which obscured the true state of affairs in this case were the complete absence of pain and vomiting. Carter and Giuseffi[8] have pointed out the diagnostic value of bloody or serosanguineous intrapleural fluid in strangulated diaphragmatic hernias. In this case, however, the bloody fluid was interpreted as being

* From the Surgical Service, Nichols V. A. Hospital and the University of Louisville School of Medicine, Louisville, Ky. Published with the permission of the Chief Medical Director, Dept. of Medicine and Surgery, Veterans Administration, who assumes no responsibility for the opinions expressed or conclusions drawn by the author.

a traumatic hemothorax later becoming infected. In retrospect, the diagnosis might have been suspected from the recent stab wound which could have lacerated the diaphragm but the correct interpretation of the x-ray (Fig. 1) showing a hollow viscus in the left thorax would have confirmed the diagnosis. It is interesting to note that strangulation and gangrene of the fundus caused no pain or vomiting in this patient. The probable reason for this astonishing lack of symptoms is that the stomach was not obstructed.

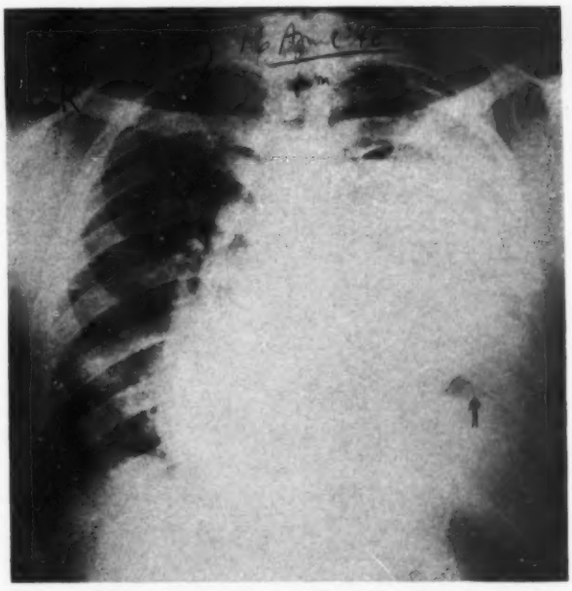
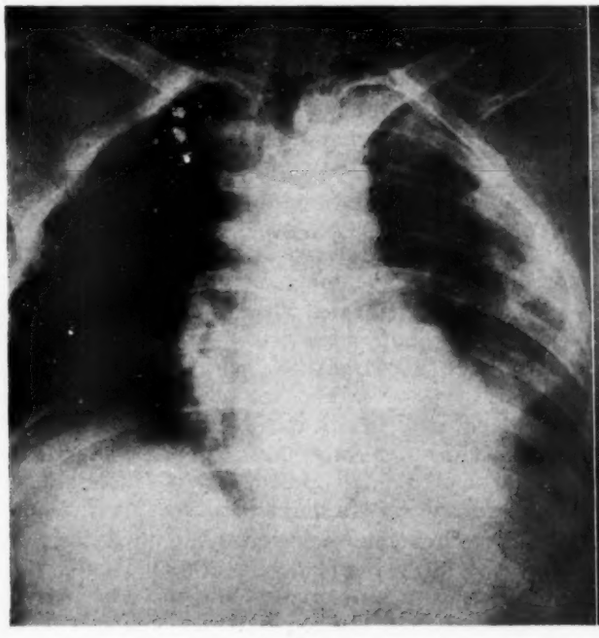


FIG. 1. Shows apparent massive left pleural effusion with displacement of heart to the right; arrow points to gastric bubble within left thoracic cavity. Case 1.

CASE II. O. W., a thirty-eight year old, white, male contractor, was first admitted to Nicholas Veterans Administration Hospital on October 10, 1947. In an auto accident he had fractured six left ribs (five through ten) near their angle and had sustained a severe head injury resulting in a left hemiparesis. X-ray of the chest (Fig. 2) taken at this time showed only the fractured ribs. While in the hospital the patient developed severe, deep thrombophlebitis of the right leg and thigh which was treated by anticoagulants.

On September 5, 1948, he was readmitted to the hospital with a tentative diagnosis of penetrating ulcer. For fifteen years he had had intermittent, ulcer-like, epigastric pain relieved by alkalies. These symptoms became worse in the two or three weeks preceding admission and the day before admission he was seized with a very severe, cramping, epigastric pain radiating to the right scapula and left shoulder. He was nauseated and vomited repeatedly.

Physical examination revealed an acutely ill male who lay flat in bed moaning and retching at frequent intervals. Chest findings were reported as negative. Abdominal examination revealed voluntary spasm in the upper abdomen and moderate to



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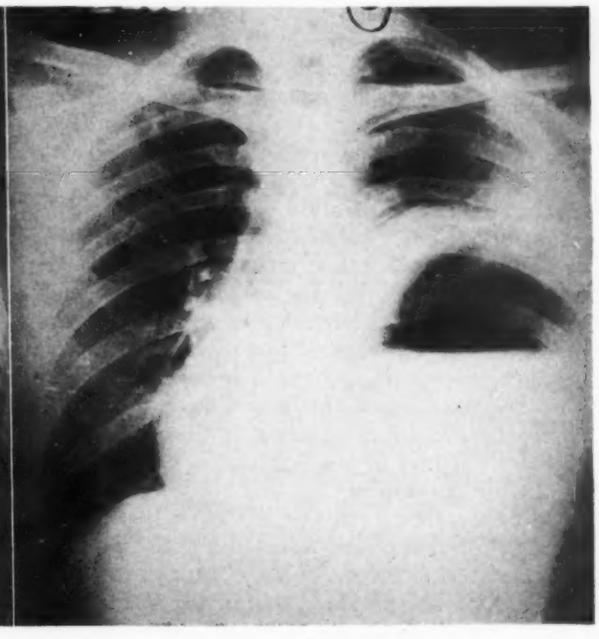

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FIG. 2. Nothing definite to be made out in the illustration except for numerous fractured ribs on the left. Case II.

FIG. 3. This could be either eventration of left diaphragm or diaphragmatic rupture with stomach lying within the left thorax. Note also the displacement to the right of the mediastinum. Case II.

FIG. 4. Barium swallow reveals the high-lying stomach. This could be eventration of left diaphragm of herniation of stomach into left chest. Case 11.

marked tenderness in the epigastrium and gallbladder area.

Admission laboratory data was normal except for white cell counts ranging from 18,000 to 26,000 with polymorphonuclears 85 per cent and for a trace of albumin in the urine.

A chest plate on September 8th (Fig. 3) revealed marked displacement of the mediastinum to the right and what appeared to be elevation of the left diaphragm to the second anterior interspace and a large gastric air bubble. A barium swallow on September 11th (Fig. 4) showed what still was interpreted by the roentgenologists as eventration of the left diaphragm containing a dilated, distorted stomach, possibly a gastric volvulus. Scout films forty-eight hours later revealed no passage of barium beyond the stomach. The patient continued to complain of severe pain in the epigastrium, chest and left shoulder and to vomit repeatedly in spite of Wangensteen suction. He began to hiccough and run a low grade fever. It now appeared that the probable situation was obstruction and incarceration of the stomach in a traumatic defect of the left diaphragm produced by the old chest injury.

On September 14th the left chest was opened through the bed of the resected eighth rib. In the left chest 200 to 300 cc. of hazy orange-brown fluid were found. The proximal half of the stomach was tightly incarcerated in a laceration of the diaphragm 5 cm. long, extending obliquely forward and to the left from a point about 2 cm. from the esophageal hiatus. (Fig. 5.) There were ischemic necrosis and marked edema of both the posterior rim of the diaphragmatic defect and also of the imprisoned portion of the gastric fundus immediately adjacent to the cardia. The diaphragmatic defect was enlarged by incising the anterior end for about 6 cm. As the stomach was being freed, the necrotic area mentioned previously gave way and there was a spill of musty-smelling gastric contents mixed with barium. When the devitalized portion of stomach, cardia and adjacent esophagus had been excised, a defect was left in the anterior aspect of the esophagogastric junction about 7 by 2½ cm., leaving the esophagus attached to the stomach by a narrow bridge of wall 1½ cm. in width. (Fig. 6.) It was, therefore, necessary to divide the esophagus completely and reimplant it in the fundus of the stomach and to close the large defect left at the cardia. As it was impossible to approximate the rigid edematous margins of the diaphragmatic defect or to return the stomach entirely to the peritoneal cavity without undue tension, the margins of the unyielding diaphragmatic defect were tacked around the upper gastric fundus with interrupted cotton stitches as shown in Figure 7. This maneuver satisfactorily closed the diaphragm without any apparent distortion or constriction of the stomach. The lung was then reexpanded and the chest closed around a catheter for suction drainage.

Although the wound healed well, the patient did poorly. Already badly depleted, he developed a patch of pneumonia in the right lower lobe, homologous serum jaundice and a recurrence of thrombophlebitis in the right leg and thigh. The pneumonia and jaundice cleared up under appropriate therapy and the phlebitis was treated by left superficial femoral vein ligation and anticoagulants. When oral intake was resumed, the patient vomited most of what he received and a barium swallow revealed marked gastric atony similar to that seen after vagotomy for peptic ulcer. It was feared that the stomach might have again become strangulated so on September 28th he was re-explored through the original left thoracotomy incision. The diaphragm was found well healed around the upper gastric fundus without constricting or distorting it. Through a short gastric incision the esophagogastrostomy stoma and the gastric mucosa were inspected and found to be normal, the stoma easily admitting two fingers. The thoracotomy wound was quickly closed and a Hendon type jejunostomy for feeding was then carried out through a short upper left abdominal incision. Palpation of the stomach below the diaphragm revealed no abnormality or abscess. The patient was returned to his bed but four hours later he suddenly died. Autopsy revealed massive right pulmonary embolism, the source apparently being the recurrent deep thrombophlebitis of the right lower extremity.

Although the ulcer-like background in this case caused some confusion at first, we should have diagnosed the condition earlier from the following features: (1) the history of a crushing injury of the chest which might have resulted in a rupture of the diaphragm; (2) the severe epigastric pain with suggestive radiation to the left shoulder; (3) the persistent retching and vomiting; unfortunately we cannot derive the full significance of this symptom since it was not accurately observed whether or not bile was present in the vomitus; (4) hiccough and (5) the x-ray picture. Although at first this was interpreted as eventration of the left diaphragm, it was equally indicative of a dilated stomach lying *above* the diaphragm.

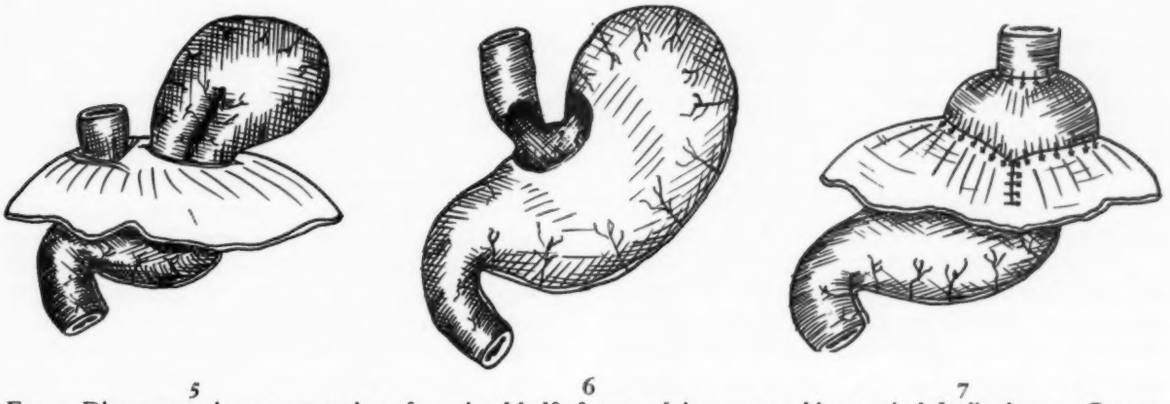

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FIG. 5. Diagrammatic representation of proximal half of stomach incarcerated in rent in left diaphragm. Case 11.
FIG. 6. Defect left when necrotic tissue resulting from pressure necrosis was trimmed away; the margins of this extensive defect were porky and edematous. Case 11.
FIG. 7. Sketch representing reconstruction of esophagogastric continuity and repair of diaphragmatic defect by tacking diaphragm to upper gastric fundus; closure of defect in cardiac region not shown here. Case 11.

It is interesting to note that this patient with a completely obstructing strangulation of the stomach had severe pain and vomiting although there was only localized pressure gangrene, whereas the previous patient remained symptom-free with non-obstructing strangulation and mass gangrene of the gastric fundus. Pathologic examination in this case confirmed our clinical impression that there was acute, localized, ischemic necrosis and not a perforated peptic ulcer at the site of pressure.

This patient unfortunately died of an unrelated condition. Nevertheless it would appear that the surgical repair itself was satisfactory and should be just as applicable to this condition as it is to the reconstruction following the "Sweet operation" for cancer of the esophagus or to esophagogastrostomy in resections of the proximal stomach.

COMMENTS

Carter and Giuseffi[8] found that traumatic diaphragmatic hernias constitute over 90 per cent of cases complicated by strangulation. It might also be added that practically all diaphragmatic hernias are left sided. Of Harrington's 430 cases, 98.4 per cent were on the left side.[2]

Certain characteristics of these strangulated diaphragmatic hernias are helpful in their diagnosis, namely, (1) history of an injury, crushing or penetrating, that might have lacerated the diaphragm; (2) pain, characteristically severe, usually located in the upper left abdomen and left chest and occasionally radiating to the left shoulder; (3) severe and repeated vomiting in most cases; it will be noted that these last two symptoms are no more than one would expect in any gastric or intestinal obstruction. The important thing is, in obscure cases, to consider the diaphragm as well as the inguinal canals or previous operative adhesions as possible sites of obstruction. In our review of forty-five case reports of strangulated diaphragmatic hernia we were interested to find that progress in strangulated diaphragmatic hernia toward gangrene or necrosis is not necessarily indicated by the severity of pain and vomiting. Thus 66 per cent of those patients with strangulation but no gangrene had severe pain whereas severe pain was present in 81 per cent of those who had progressed to gangrene. In like manner, 69 per cent of patients with strangulation only vomited repeatedly and severely whereas 81 per cent with strangulation and gangrene had

the same degree of vomiting. (4) As in other diaphragmatic hernias, varying degrees of dyspnea and respiratory distress may be present. (5) Suggestive chest signs are usually present. These include variations of tympany, dullness and adventitious sounds in the left chest and moderate to marked displacement of the heart to the right. (6) Bloody pleural fluid, as pointed out by Carter and Giuseffi, does not infrequently accompany a strangulated or gangrenous herniated viscus. (7) X-ray will usually be the final and sometimes the only diagnostic finding. Thus in our first case correct interpretation of the x-ray would have made the diagnosis in spite of other misleading findings.

The treatment of strangulated diaphragmatic hernia should be surgical as an emergency measure as soon as the patient can be prepared. There is still some difference of opinion as to the ideal approach but in the two cases presented and in the few others with which we have had experience we have been completely satisfied with the thoracic. This route seems to expose the pathologic condition most clearly and on several occasions it would have been virtually impossible to have dealt with adhesions and other disorders from an abdominal approach.

SUMMARY

1. Two cases of diaphragmatic hernia of the stomach with strangulation and gangrene are presented.

2. Strangulated traumatic hernia through the diaphragm is briefly discussed.

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DISCUSSION OF PAPERS BY DRS. BLADES, CAMERON, O'ROURKE AND BURT, IOVINE, GRISWOLD, AND HAMILTON AND PHILLIPS

E. J. O'Brien (Detroit, Mich.): I hesitate to discuss these papers because I heard only the last two of them. Dr. Blades (I imagine) told you what is uppermost in my mind, i.e., the similarity of the treatment of traumatic injuries to the chest and the postoperative treatment of all major thoracic surgery. One must always keep the air passages dry, watch for wet lungs, know how and when to block nerves to ease pain and facilitate raising sputum, encourage a patient to cough and help him by supporting the chest, etc. One must always be ready to bronchoscope and aspirate either air or fluid from the pleural cavity and to decorticate early if an organized pneumothorax exists.

I saw the last of the movie that Dr. Iovine presented on decortication and would like to emphasize its importance. In spite of all the papers by Drs. Blades, Tuttle, Burford, Langston and others, decortication is often delayed too long or a thoracoplasty is done to obliterate the pleural cavity. Many of these people get excellent results by freeing the lung from its thick visceral pleura so that it may fill the hemothorax and preserve some lung function. We get some startling results even in tuberculosis if the disease in the lung has not been too extensive.

I was very much impressed with Dr. Griswold's paper on injuries to the mediastinum and should like to add a word about injuries to the bronchi. In 1947 we read a paper in which we reported on a series of dogs upon whom a section of the bronchus was removed and the cut ends sutured. There was one on a human. These healed uniformly. When I was in Hawaii in January, Dr. Paul Gebauer had done four dermal transplants on humans to close the gap in the bronchus after a stenosis was resected. All patients did well. Since I came back we have operated upon numerous dogs using portions of trachea and bronchi to fill a gap in the bronchus. They all healed. In many we used specimens of trachea and bronchi that had been preserved for weeks. In some dogs as much as 2 inches of bronchus were resected and a preserved cylindrical specimen replaced. These wounds also healed.

Usually there is not much use in doing this procedure because the lung distal to a stenosis is usually bronchiectatic or destroyed, especially in tuberculous patients, but in traumatic stenosis or as a prophylactic measure after an injury I can assure you that it can be done with safety and with excellent results. It will save many individuals

from developing stenosis and will preserve many lungs.

HOWARD E. SNYDER (Winfield, Kan.): I looked forward to discussing this series of papers because I expected to hear something with which I should disagree. I did not.

I think they have emphasized one thing, namely, that the cardinal principle in treating a chest injury is relief of or avoidance of cardiorespiratory embarrassment whether it is by taking care of a sucking chest wound, a hole in the chest wall, aspiration of blood or fluid from the pleura, aspiration of blood or mucus from the trachea by one means or another, deflation of a dilated stomach, relief of pain by intercostal nerve block or, finally, the avoidance of strapping of the chest. All of them are designed to give the individual a cardiorespiratory mechanism which will work. They must be done as rapidly as possible and it must be remembered that any of them may be factors in shock and must be considered in dealing with the patient in shock.

I think the same principles may be carried over into the care of any surgical or injured patient, particularly one who has an injured abdomen or an abdomen which has had surgery performed upon it because the so-called wet lung, which is really the result of one or more of the factors mentioned, may develop in that patient as well.

L. M. SHEFTS (San Antonio, Tex.): I thought Dr. Cameron's paper helped to underline the statement made by Dr. Blades, that trauma certainly paid no attention to anatomic barriers; because when you realize the percentage of associated injuries that his patients had, the statement becomes very obvious. In the last World War, of 21,000 listed wounded soldiers 46 per cent had multiple injuries that is, important multiple injuries. A considerably smaller percentage is found in civilian practice.

I should like to say just one thing about wet lung. There is a great deal of talk about it and there is a great deal more talk than there is understanding. The mechanism by which it arises is not too well understood. I had certain ideas in Africa, changed them in Sicily and then changed them markedly near the end of the campaign in Italy. Many cases of wet lung will, in my opinion, promptly disappear if the patient is made to cough thoroughly from the very onset of this condition. Provisions must be made to insure relief from chest-wall pain when using intercostal blocks so that the patients will cough.

I think too many things are excused on the basis of the so-called wet lung. In the first place, if one pays attention to a clean, dry tracheobronchial tree and obtains and maintains it, there will be far fewer cases of so-called wet lung. I believe it starts on the inside and not from the trauma on the outside. In the process of treating other things when opening chests, you see huge hematomas in the parenchyma of the lung and these patients do not have wet lung, whereas other patients suddenly get pulmonary edema. I think that eventually somebody will work out the exact mechanism of the thing but it is still far from answered.

One thing I should like to mention in relation to Dr. Cameron's excellent paper is that the subcutaneous emphysema he mentioned can be present without any rib fractures. It can be caused by rupture of the parenchyma of the lung, with air going into the interstitial tissues, the mediastinum, the neck and out over the body with a swelling-up like the proverbial toad. As Dr. Griswold pointed out, there are very, very few of those patients who ever need any incisions in the skin. I mention this only because I do not agree with the fact that these should be treated by tyring to institute a local-area pneumothorax with decompression by catheter. I think if the pneumothorax space is not present by injury, for heaven's sake, do not make one! I think many of our complications arise from the fact that we sometimes cannot expand the lung to begin with. If it is expanded when we get it, leave it that way.

In reference to Dr. Iovine's paper I was amazed with the tremendous amount of material he covered in the short space of time. There is only one thing I should like to add to his fine paper. When the patient comes in with a penetrating or perforating wound of the chest, the question always arises in each case: Will this patient have to have surgery or not? The inexperienced person is very much upset by the patient coming in, short of breath, with hypertension, cold clammy skin, etc. Unfortunately in civilian practice many of those patients are taken to the operating room and operated upon. In a review of three different hospitals the mortality rate was almost a little less than twice the percentage of the mortality we had in field hospitals.

The difference was in one fact only. All the things that Dr. Iovine mentioned in the care of the patient, in a sense, might be called preoperative management. If that is all carried out, when you are through you often find that you do not have to operate upon the patient; that is, you stop the pain and let him cough to clear his tracheobronchial tree. One good cough by a patient is better than a bronchoscopy. If you can do that immediately, you will find that the blood pressure rises, the skin gets a little warm with a slight rosy tinge and the patient changes completely. But you do have to stop his pain to get him to cough; that is important.

After you have provided for the blood loss with blood and not plasma, I am convinced that there will be fewer operations for penetrating and perforating wounds of the chest than are so frequently done.

There are two other points I should like to make.

One is the matter of tension in the thorax. We listed in our series in the surgical group that Dr. Iovine spoke about, the Second Auxiliary Surgical Group, a large number of tension pneumothoraces. I began taking pleural readings on every patient who came in and I discovered a very interesting fact, namely, if a reading is taken on every one of the patients with a hemopneumothorax, it will be seen that these patients have a positive pressure, at least on their expiration if not on both inspiration and expiration. They may not necessarily be short of breath. On many occasions if you aspirate them, take a reading and then remove the blood, you will find that the so-called tension pneumothorax was never a tension pneumothorax at all and would not be.

In my own personal series of 265 major thoracic injuries I had only three tension penumothoraces that answered those rules, that is, three in which I had to go back in and retap. Without an increase of blood pouring into the chest, thus increasing the pressure of the air, the second or third reading showed a definite and sudden build-up of pressure. When tension pneumothoraces have to be decompressed, they are not to be decompressed by a needle. This is the only thing on which I would disagree in the slightest with what Dr. Iovine has said. It is too haphazard; it shuts off too quickly. If a tension pneumothroax must be decompressed, it must be done with a catheter and a good sized one, hooked up to a water trap bottle.

I should like to be slightly presumptuous and suggest a method about which Dr. Griswold spoke concerning injuries to the esophagus. There is a combined method of suturing the esophagus and draining the mediastinum at the same time. If one goes in on the right side (which, of course, is a fortunate side on which to handle an esophageal tear) and finds a tear in the esophagus, a suture of the esophagus is done primarily. With the patient on his left side, a long, 3-inch needle is shoved out in the intercostal space, right through the back; the hub is shoved right down into the intercostal space and pleura, a rubber drainage tube is packed in there, too, and then the mediastinal pleura is closed. The chest is then closed, the lung expanded and an incision is made around that needle and a small segment of rib removed. When you reach in and pull out the rubber drain, you have an extrapleural mediastinal drainage of the sutured side of the esophagus.

Lester Breidenbach (New York, N. Y.): Speaking of hemothorax, Dr. Tillett at New York University has developed a material, which is a metabolic product of streptococci, which he has called streptokinase and streptolysin. We have had some small experience with this material in that we aspirated the blood from the chest cavity and applied the streptokinase or streptolysin (he now calls it streptokinase) which has the faculty of setting up an enzymatic or anti-enzymatic process which dissolves the fibrin; then twenty-four or thirty-six hours later the chest is re-aspirated and the fibrin remains entirely liquid.

By that particular method of treatment none of these patients who have been treated that way with this new material has developed an organizing hemothorax which required decortication later. It is apparently going to work or is working very efficiently. The experience has been with only about thirty patients, two of whom I have seen treated on our service. Both did very well with expansion of the lung very quickly so that none of them ever required decortication.

Duncan A. Cameron (closing): I should like to thank all of the discussers for their comments. I believe only one or possibly two specific points were directed to our paper in particular. The first was the question in the discussion of Dr. Shefts having to do with the placement of a thoracotomy tube in the treatment of rapidly progressing subcutaneous emphysema which we had commented upon. His comment was that we should leave that pleural space inviolate.

The reason why we have used this thoracotomy tube was that we had a specific location for the supposed injury to the lung, at the site of the fractured ribs, and we believed that there was an associated pneumothorax although the roentgenogram did not show it. We have noted that with pneumothorax the placement of a thoracotomy tube generally is followed by a subsidence of all ordinary subcutaneous emphysema. We have used this method on a couple of occasions and it has seemed to work so we have concluded that there was a pneumothorax space present although it did not show in the x-ray.

As for the wiring of fractured ribs, I think our only comment is that we were interested in analyzing multiple fractures of the ribs not from the standpoint of the ultimate healing of the rib itself, which in 109 cases was never of any concern to us; but we were interested instead in pointing out that multiple fractures of the ribs are as erious problem from the standpoint of disturbance of cardiorespiratory physiology and the complications which follow in the pleural space.

John C. A. Gerster (New York, N. Y.): Dr. Blades, I do not think Dr. Jones made himself clear. What he talked about was the sucking wound with a number of ribs each broken in two places. In their series at Richmond the doctors immobilized such sucking wounds of the chest wall by wiring of adjacent rib ends. There was great comfort immediately after such wiring of the ribs.

Vincent M. Iovine: (closing) I should like to answer Dr. Shefts' comment first on the question of the use of simple apparatus, such as I mentioned, for decompression of a pressure pneumothorax. I thought I made the point that that was strictly

an emergency procedure and certainly the use of the intercostal catheter is much to be preferred if it is available. I did state that under field conditions the most available thing was usually a fairly large needle which works effectively until the underlying pathologic disorder can be straightened out.

I am not sure I understood the question of the last commentator. I do not see actually, however, if this answers the question, how wiring of multiple fractured ribs would guard against paradoxical respiration in a patient with a severely injured chest wall and a crushed chest. I think Dr. Cameron pointed out the type of immobilization that was necessary and the application of the particular type of instrument he used in conjunction with the use of traction.

The value of Dr. Cameron's paper, I think, is in emphasizing the physiologic approach to the treatment of severe chest wounds. He certainly has presented the proper attitude toward strapping of the chest and the proper treatment of the complication usually called "wet lung."

Occasionally unusual complications accompany fractured ribs and I will briefly outline one of those. A twenty-one year old Air Corps gunner entered the Walter Reed Service complaining of two and a half years of intermittent and recurrent hemoptysis. Fairly close questioning into the past brought out no history of trauma at first. He had been examined extensively from the point of view of acid-fast infection and had all the indicated procedures performed in an effort to determine the origin of the bleeding.

On careful examination of the x-ray film of his chest, a small defect in the sixth left rib was revealed and, following repeated questioning, it was learned that he had received some chest injury in the process of his extensive and severe training for his job. He was, therefore, explored and at operation a single rib fragment was found still attached at its broad base on the left to the inner aspect of the rib and the thin, sharp edge of the opposite end was impaled into the superior segment of the left lower lobe. Surrounding it there was a foreign body reaction and a small abscess. Following wedge resection of the area and removal of this foreign body, his hemoptysis ceased. I have been able to follow him four years through the Veterans' Hospital facilities and he has had no recurrence since.

R. Arnold Griswold (closing): I should like to thank Dr. O'Brien and Dr. Shefts for their suggestions in regard to repair of the old stenosed bronchus and extrapleural drainage of the esophagus.

In regard to Dr. Jones' question I certainly agree with Dr. Iovine that a much simpler method of stabilizing the chest wall in these multiple parallel fractures and preventing paradoxical respiration is traction rather than wiring.

Traction is very easily applied by simply putting a towel clip around the rib, running it up to a pulley and hanging a weight over it. You do not need a lot of fancy apparatus. A towel clip will do it and in just a few moments will change the entire picture in these patients.

Brian B. Blades (Washington, D. C.): The discussions concerning the treatment of ruptured bronchi have been extremely interesting. It might be worth while to emphasize one point which is sometimes helpful in making a preoperative diagnosis. Consideration of a ruptured bronchus should be entertained in the case of a patient who has had trauma to the thorax in whom there is no visible evidence of rib fracture but the patient has a tension pneumothorax with associated emphysema. This is particularly true if the subcutaneous emphysema precedes development of the tension pneumothorax.

Another comment I should like to make concerns the mediastinum. After any trauma to the mediastinum, particularly after the most common form in civilian life, namely, rupture with the esophagoscope or tearing with chicken or fish bones, there are two important factors to be considered: first, mediastinal pressures and second, the development of infection.

If there is a large rent in the mediastinal pleura, air leaking from the esophagus may enter the pleura and produce a pneumothorax. If, however, the rent in the esophagus has not injured the mediastinal pleura, the immediate leak of air and fluid into the mediastinum can produce a mediastinal tamponade with a fatal outcome in a very short period, certainly long before infection becomes an important factor. This is, of course, one of the principal reasons that suspected mediastinal injury, particularly injury to the esophagus, constitutes a real surgical emergency.

The last comment I should like to make concerns the use of gelfoam in cardiac surgery, particularly when the auricles are injured. Dr. Griswold has already mentioned its usefulness when needle holes produce bleeding in heart wounds after their repair. The late Horace Smithy, who revived and pioneered the very brilliant and brave work on the surgery of cardiac valves, had an amazing experience which is worth recounting. During his performance of the operation which involved inserting an instrument through the ventricle to cut a stenotic mitral valve, the valvulotome was inadvertently pushed through the valve and appeared in Doctor Smithy's hand beneath the heart after perforating the wall of the auricle. A large sheet of gelfoam was placed under the heart and held against the auricle and the bleeding was controlled. The patient survived and had an excellent result. This illustrates the dramatic usefulness of gelfoam when auricles are injured.

JOHN E. CANNADAY (Charleston, W. Va.): With reference to the presentation of Dr. Johns of Richmond, Virginia, with regard to the treatment of rib fractures by wiring, I was present with a group of surgeons at White Sulphur Springs a few months ago when Dr. Coleman of Richmond and others presented a method of treating fractures of the ribs as they would fractures of other long bones. To make it short, they were approximating the broken ends of the ribs and wiring them.

In the case of consecutive multiple fractures of the ribs, they usually made a long, more or less vertical incision exposing the fractures and wired each rib at its point of fracture. In other cases of multiple fractures they may make a U-shaped incision so as to expose the double fractures of several consecutive ribs.

I talked also with a number of members of the surgical staff of the hospital of the Medical College of Virginia where they have adopted the method as a routine and are treating all fractures of the ribs in that manner. They state that the period of convalescence has been greatly shortened and that the patients have been made infinitely more comfortable than heretofore. A person who has not had a fractured rib does not realize the discomfort and pain incident to it and the prolonged soreness incident to slight movements of the rib. Having had a fractured rib myself, it is my opinion that the use of adhesive strapping greatly adds to the discomfort. I believe that the fixation of the fractured rib, treating it as one would the fracture of a long bone elsewhere, has a sound basis of merit behind it. In regard to the hazards incidental to rib fractures I recall that some of the older English surgeons used to say that fracture of six consecutive ribs usually was followed by death. They commented thus when the body of a Roman soldier was exhumed somewhere in England and it was found that he had had six or seven consecutive fractured ribs and had recovered.

THORACICO-ABDOMINAL APPROACH TO RUPTURE OF THE LIVER*

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FORTUNATELY, massive rupture of the liver following trauma is not common but the condition must be given serious consideration since failure to handle it quickly and competently almost invariably means the loss of a life. The signs and symptoms are those of intra-abdominal hemorrhage; a differential diagnosis as between rupture of the liver, rupture of the spleen and a torn mesenteric vessel cannot usually be made. However, in any case it is obviously necessary to open the abdomen without delay.

The patient is usually in shock and should be given intravenous therapy in the form of plasma and whole blood as soon as possible. The stomach contents should be emptied through a Levin tube. In fact this should be done in all such cases of emergency surgery since it is not uncommon for these patients to have their stomachs filled with a conglomeration of hot dogs, coco-cola or beer at the time of their injuries. If the patients should vomit while under anesthesia, a small amount of this vomitus aspirated into the trachea might cause death.

Before the incision is made, the surgeon should, if possible, be well fortified with 4 to 5 pints of whole blood. The anesthetist should be prepared to insert an intratracheal tube or at least carry the patient on positive pressure anesthesia in case it should be necessary to enter the thoracic cage. Either a right or a left rectus incision is made depending on the point of maximum tenderness. From this incision it is usually possible to determine the nature of the injury. If the tear in the liver is small and easily approached, it is usually sufficient to pack it with one of the absorbable sponges which should be held in place by an absorbable suture placed with an atraumatic needle. However, in cases of severe lacerations and especially those extending to the more inaccessible areas of the liver, it is often impossible to control the hemorrhage from this approach and it becomes imperative to secure a more adequate exposure. For this purpose the thoracico-abdominal incision is the ideal procedure. It gives remarkably good exposure and is well tolerated under positive pressure anesthesia. Every surgeon who cares for trauma patients should be familiar with the incision.

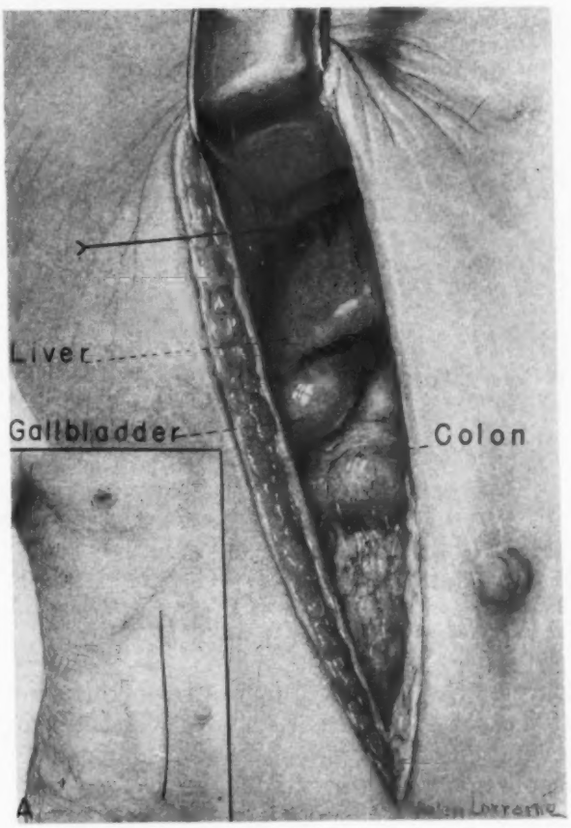

FIG. 1. Arrow points out the lower end of the laceration that could only be visualized by lifting up the upper end of the incision with a right angle retractor; insert A; the right rectus incision used.

One of us (J. W. D.) first learned of this incision from Chamberlain[1] while working with him in Okinawa. The historic development of this type of incision was covered by Carter[2] who describes in detail not only his own incision but the variations used by several other surgeons.

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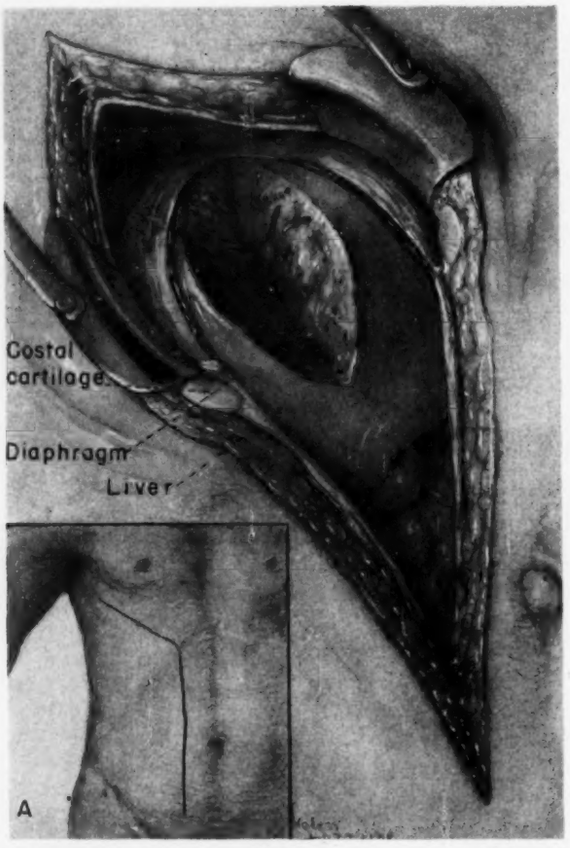

FIG. 2. The thoracic extension between the fifth and sixth ribs; right lung collapsed; diaphragm opened showing exposure of extensive laceration of liver.

Harper[3] has also recently described this type of incision which he has used successfully in several different types of cases including three diaphragmatic hernias. MacManus[4] and Garlock[5] have used it in operating upon neoplasms of the cardia and esophagus. All report with considerable enthusiasm on the results obtained. In traumatic surgery the exact type and location of the incision will vary with the individual injury.

We wish to report an illustrative case in which the massive hemorrhage, in our hands, could not have been controlled without the use of the thoracico-abdominal approach.

CASE REPORT

The patient, an eighteen year old male, was admitted to the hospital on February 21, 1948, an hour after he had been injured in an automobile accident. He had been thrown from a truck in such a way that his body had been wrapped around a wooden post. The patient had been in a semiconscious condition and had not spoken since the time of his injury.

Examination showed a well developed, well nourished eighteen year old male who moaned and held his abdomen but would not respond to questions. There were some abrasions about the neck and face. The chest was clear to percussion and auscultation. The heart was not enlarged and there were no murmurs. The sound was distant, the rate rapid and regular. Blood pressure was 90/40. There were no obvious fractures or dislocations. The neuromuscular reflexes were sluggish but present and equal. The patient had pediculosis pubis. There seemed to be more tenderness in the right side, but the entire abdomen was held rigid, and the patient did not respond sufficiently for the tenderness to be definitely localized. X-rays were of no diagnostic value. A catheterized urine specimen showed gross blood. The blood picture was 3,230,000 red blood cells, 21,650 white blood cells, 10.2 Gm. or 66 per cent hemoglobin, 82 polymorphonuclear leukocytes and 18 small monocytes.

The patient was given plasma while in the accident room and, fortunately, 3 pints of whole blood which matched the patient's were available in the blood bank. These were administered during the course of the operation.

A right rectus incision was made under satisfactory general anesthesia. (Fig. 1.) The peritoneal cavity was found to be filled with blood. The spleen and mesentery were intact, and the anterior portion of the liver appeared to be normal. However, exploration up under the dome of the diaphragm revealed that the right lobe of the liver was almost completely severed, leaving two profusely bleeding liver surfaces, approximately 5 inches in diameter on each side. A large laparotomy sponge was placed in the laceration but bleeding continued to be profuse. Only the lower end of the laceration could be visualized by lifting up the upper end of the incision with a right angle retractor.

At this point the nurse anesthetist was told that we were going to enter the thoracic cage. Unfortunately, no one was immediately available to insert an intratracheal tube. Under positive pressure anesthesia the incision was extended up to approximately the sixth rib. The costal margin cartilage was cut through and the thoracic cage entered between the sixth and fifth ribs. The diaphragm was cut between Kocher clamps, thus exposing the dome of the liver. (Fig. 2.) The hemorrhage was controlled by placing the hand beneath the liver and packing the laceration with twelve gelfoam sponges. Interrupted mattress sutures of chromic catgut were placed in the liver. (Fig. 3.) This was reinforced with two-inch gauze packing which was brought out through the abdominal incision. Further exploration revealed that there was a small amount of retroperitoneal bleeding in the region of the right kidney. The operative wound was closed by using continuous catgut sutures for the peritoneum and pleura and continuous chromic

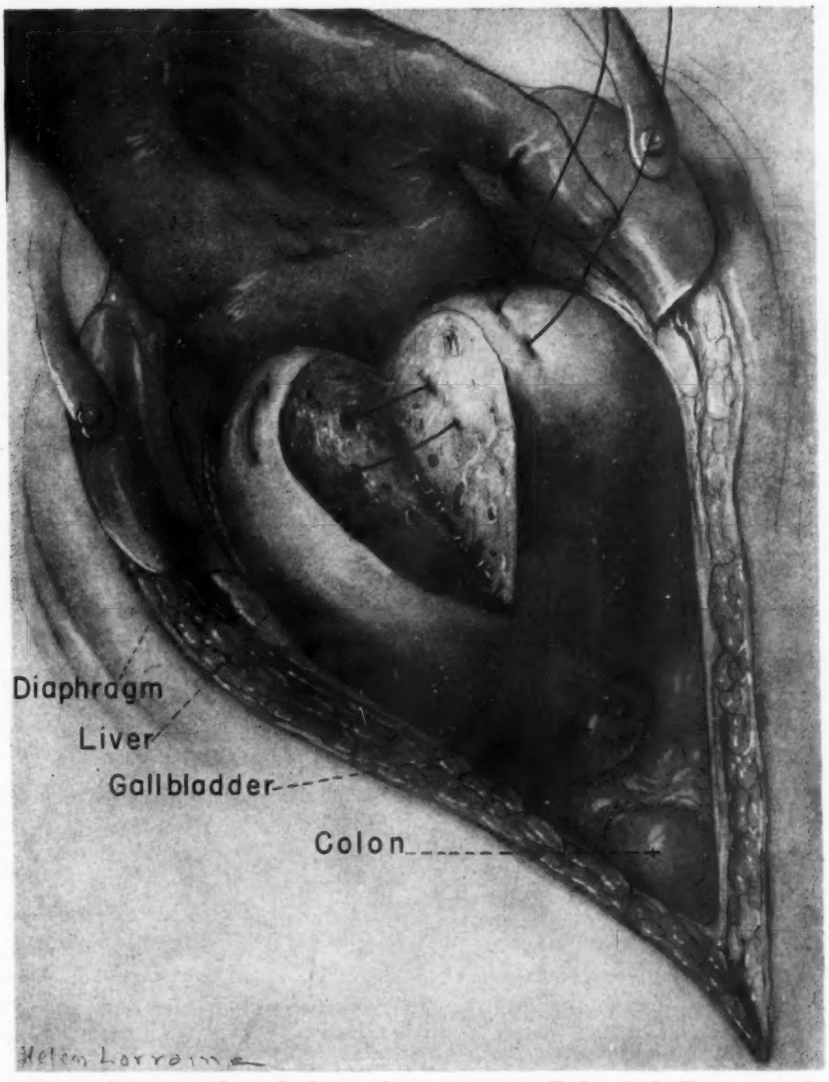

FIG. 3. Illustrates how the hemorrhage was controlled and the liver sutured.

catgut reinforced with interrupted chromic sutures for the fascia and intercostal muscles. The skin was then closed with interrupted black silk sutures. The chest was closed without drainage.

At the end of the operation the patient's blood pressure was 110/90 and his pulse was 140. His condition was considered critical but better than it had been at any time since the accident.

In addition to the three pints of blood administered during the operation, the patient was given another 500 cc. the following morning. Penicillin was administered in doses of 100,000 units every three hours from the time of admission on February 21st until April 1st, then in doses of 50,000 units every three hours until April 17th. On February 24th (the third postoperative day) the patient's blood count showed 3,540,000 red blood cells and 10.05 Gm. or 71 per cent hemoglobin. On February 27th (the sixth postoperative day) the gauze packing was removed under pentothal anesthesia.

For the first two or three postoperative days the patient was irrational and removed his bandages several times attempting to scratch the pediculi before they were eradicated resulting in a wound infection. If treatment of the pediculosis had not been overlooked due to our attention being focused on the more glamourous aspect of this case, the wound infection would probably not have occurred. A localized empyema also developed which cleared up promptly following open drainage by resecting 1 inch of the eighth rib. This complication might have been prevented by suction drainage of the chest for a few days following operation.

The patient was followed during his postoperative course by the medical service. In regard to hepatic insufficiency it was their opinion that he showed no signs of this. The hematuria cleared up without treatment. The patient was discharged after sixty-one days' hospitalization. He has been seen each month since that time and is now

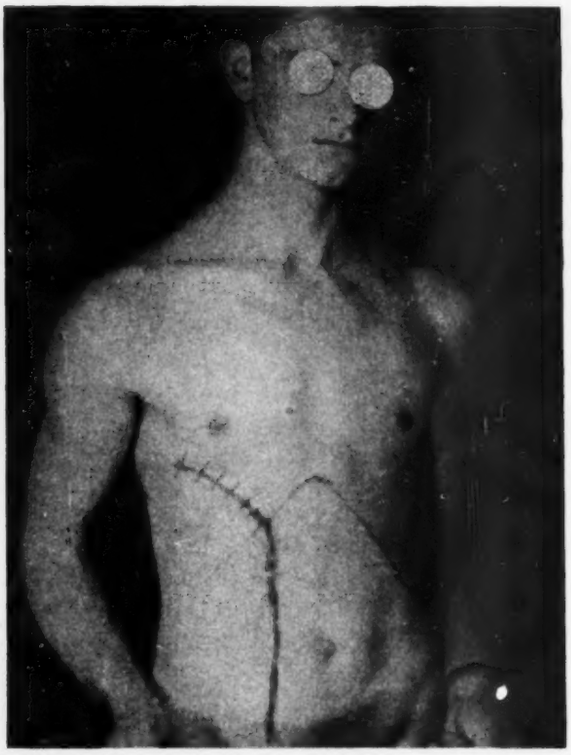

FIG. 4. The patient seven months postoperatively showing the healed scar; the cross marks illustrate the thoracic extension.

symptom-free, has gained weight and is back at work. (Fig. 4.)

SUMMARY

No claim of originality is made for the thoracico-abdominal incision. It was demonstrated to me by Chamberlain while working with him in Okinawa. But we consider that its application in case of liver trauma offers such marked advantages that any surgeon who cares for trauma patients should be familiar with the procedure. The exact type and location of the incision will depend upon the individual injury. In the case presented a severe laceration of the right lobe of the liver was successfully repaired through a thoracico-abdominal incision. We believe that no other approach would have given the necessary exposure.

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MASSIVE RUPTURE OF THE LIVER*

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IN civilian medical practice massive rupture of the liver is fortunately a rare clinical problem. It is not that the entity is uncommon in this era of speedy aerial and surface transportation for it occurs often in immediately fatal airplane and automobile accidents. Nevertheless, on any list of hospital admissions massive rupture of the liver presents a very low incidence since most patients expire immediately or shortly after the accident.[1–4]

Increased knowledge of indications for exploration in closed abdominal injuries, availability of blood, blood fractions and blood substitutes, and development of antibiotic therapy to its present high level have improved the surgical management of these cases. Resection of large masses of hepatic tissue or even complete resection of the left lobe of the liver for tumor is now being done with an acceptable mortality by means of meticulous surgical technics.[5–8] However, repair or reconstruction of the massively ruptured liver with adequate control of hemorrhage still remains nearly unsurmountable. Extensively pulped or lacerated liver tissue is quite impossible to suture satisfactorily even with the most meticulous of technics. Recurrent or secondary hemorrhage, often fatal, attends the most earnest effort at hemostasis. Failure to débride non-viable liver tissue may result in sequestration, sepsis, secondary hemorrhage, hepatorenal decompensation and death.[11–17] The over-all mortality of liver rupture in general remains around 60 per cent, that of the massively ruptured cases being very much higher.[2,4,9]

At the present level of development of surgical technic, adequate débridement and reconstruction of such massively ruptured livers is thwarted mainly by the lack of a safe and effective technic for hemostasis; it is generally believed that hemostasis is the greatest single problem in hepatic surgery.[2,9] Recent reports have strongly recommended the use of oxidized cellulose and gelatin sponge alone or in combination with soluble thrombin as hemostatic agents in hepatic surgery.[10] Sano and his coworkers have described a coagulum-contact, non-suture technic of repairing hepatic defects with impressive experimental evidence of its efficacy. Jenkins et al. have also presented evidence of the effectiveness of gelatin sponge and soluble thrombin solution in experimental hepatic and cardiac surgery in animals and in human patients after surgical biopsy of the liver.[18–23]

CASE REPORTS

The following two cases of massive hepatic rupture with survival in which a similar non-suture technic of débridement and hepatic reconstruction was employed illustrate certain advantages and disadvantages of these methods in surgical practice.

CASE 1. M. A., a twenty-six year old white male was crushed between an overturned loading truck and a heavy concrete guard rail at 12:45 P.M. on April 30, 1947, about thirty minutes after eating a heavy lunch of meat, potatoes, beans and pie. He was able to extricate himself and walk a few steps but he then collapsed with pain in the abdomen and chest. When examined ten minutes later he was quite pale, restless and seemed hysterical. He complained of severe right upper abdominal pain and of pain in the right shoulder of a deep aching intensity (Kehrer's sign). There was an area of contusion and ecchymosis over the right lower thoracic cage in the mid-axillary line. His abdomen was board-like. His pulse was 100 and his blood pressure 130/80. He was not nauseated. Despite the board-like rigidity there was exquisite tenderness in the right upper abdomen and right flank as well as generalized tenderness throughout the entire abdomen.

At the plant dispensary plasma was immediately started intravenously. With it running continuously the patient was brought to the hospital by ambulance. It was believed that the patient had suffered a rupture of the liver and, possibly, of the food-filled stomach.

On admission to the hospital preparations were

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made for the transfusion of whole blood. Because the patient's blood pressure had been well maintained on the ambulance trip to the hospital, he was taken immediately to the operating room where a continuous whole blood transfusion was started and an exploratory laparotomy was begun less than an hour after receipt of the injury.

An extensive transverse incision was made in the upper abdomen revealing two tremendous stellate lacerations involving about two-thirds of the right lobe of the liver. There were about 2½ pints of free and partly clotted blood already in the upper abdomen and fresh bleeding was issuing from several large lacerations. There were two major clefts in the right lobe of the liver which extended vertically from the free inferior margin of the right lobe over the diaphragmatic surface or dome of the liver up to the coronary ligament. The more lateral of the two clefts practically amputated the lateral third of the right lobe of the liver. The medial cleft was exceedingly deep and nearly transversed the entire thickness of the liver in an anteroposterior direction. The entire hand could be laid within this cleft with ease. From these two major clefts innumerable smaller fissures extended in all directions involving an area estimated to be at least two-thirds of the right hepatic lobe. In and around all of the larger fissures was a quantity of pulped liver tissue mixed with clotted blood which was removed with the suction tip much as the neurosurgeon removes a highly cellular brain tumor. Because the viability of the partially amputated lateral third of the right lobe was extremely doubtful, it was decided to complete the amputation by resection. The raw surface left by this procedure was covered with a large, dry sheet of oxidized cellulose gauze (oxycel) held pressed in place by means of a warm lap sponge. The gallbladder was collapsed due to the recent meal; but since the medial cleft passed beneath it, it was impossible to be sure that the gallbladder was not torn or severely damaged on its hepatic surface. Consequently, a cholecystectomy was done. The gallbladder proved to be intact although its bed was severely torn.

The comminution of the right lobe of the liver was so extensive that suturing in any form was out of the question. Consequently, the remaining large medial cleft and the innumerable fissures of all sizes radiating over the right lobe were packed with thin, dry sheets of oxidized cellulose gauze (oxycel). The liver was then manually compressed so that all fragments were moulded together.

With the liver compressed in this fashion and held thus by the first assistant, a thorough upper abdominal exploration was carried out, mobilizing the hepatic flexure of the colon, the retroperitoneal duodenum, the head of the pancreas and the retroperitoneal common duct. These structures were examined carefully for injury but none was found. The stomach, transverse colon, both kidneys and the spleen were then examined for injury. Except for an area of contusion over the upper pole of the right kidney no other injury was discovered. There was a very large and extensive retroperitoneal hemorrhage on the right side of the vertebral column apparently arising from the liver near the dome and dissecting between the surfaces of the coronary and diaphragmatic attachments of the liver downward. At the end of the abdominal exploration, which took approximately thirty minutes, compression of the liver was discontinued and the liver was re-examined; it was found that the numerous smaller fissures seemed to be sealed off quite effectively and that the two large fragments of the right lobe divided by the major vertical cleft were held in apposition satisfactorily by the now tenaciously adherent oxidized cellulose gauze. There was no evidence of continuing free bleeding or of free biliary drainage.

The upper abdomen on the right side was then extensively drained by means of numerous large Penrose drains placed down to and into the foramen of Winslow, the right anterior and posterior subphrenic spaces, the right subhepatic space and the pouch of Morrison. A Levin tube was inserted into the food-filled stomach and the abdomen was then carefully closed in layers using interrupted silk sutures throughout. The patient endured the operative procedure surprisingly well and showed no evidence of shock.

The postoperative course during the next thirty-eight hours was marked by restlessness and gastric distention but shock or shock-like manifestations did not appear. Because of the undigested solid food mass in the stomach gastric suction was very inefficient and required continuous and arduous irrigation and lavage by the special duty nurse. At thirty-eight hours postoperatively, during a convulsive paroxysm of coughing, wound dehiscence and evisceration occurred. The patient was immediately returned to the operating room where, under anesthesia, dressings were removed revealing a wide rupture of the wound and the evisceration of most of the dilated stomach, the entire transverse colon and three loops of jejunum. Examination revealed that all of the silk sutures were in place, knots intact, but that the strands had actually ruptured or snapped under the force of the coughing. The viscera were replaced and the abdomen was closed with through-and-through steel wire sutures. The patient bore the procedure remarkably well. It is of interest that no free blood of any consequence or any sign of continuing hemorrhage or of general biliary drainage was seen during this procedure. A partial inspection of the right lobe of the liver was afforded at this time and the repair seemed intact.

Following this the postoperative course was marked by restlessness and some distention but signs of peritonitis did not appear. There was

profuse biliary drainage from the right lateral angle of the incision along the drains but the drainage was never bloody. Indeed, from the twelfth hour after the initial operation bloody or serosanguineous drainage was never in evidence.

Throughout this period supportive transfusions had been done, leaving a raw surface covered with oxidized cellulose gauze. Irrigations through the tubes were at first effective in clearing out this drainage. However, by June 3, 1947, five weeks after the accident and initial operation, there was definite clinical and x-ray evidence of a right

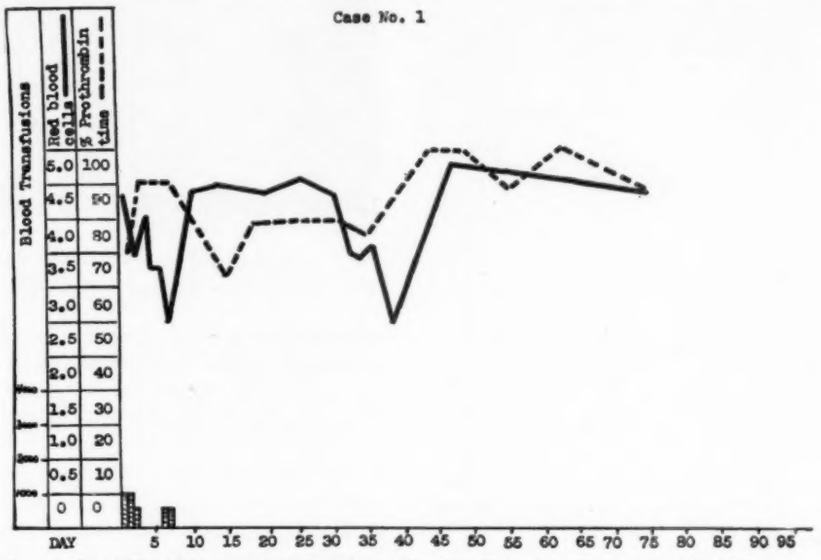

FIG. 1. Red blood count and prothrombin levels in Case 1; whole blood transfusions indicated by cross-matched columns.

of blood and plasma had been given and the parenteral administration of liver extract, vitamin B complex, vitamin C and probably excessive amounts of vitamin K had been pushed. Carbohydrate was provided parenterally by infusions of glucose solutions, protein by the infusion of plasma, whole blood or amino acid mixtures. Fibrinogen and prothrombin were supplied by transfusion of freshly drawn whole blood. By the sixth postoperative day and the fourth postevisceration day the abdomen was soft and non-distended. The patient was passing flatus freely per rectum. Nasal suction was discontinued; the tube was allowed to remain and small tube feedings of a casein hydrolysate mixture with liberal amounts of added choline and methionine were begun. (Fig. 1.)

Biliary drainage continued to be profuse and small fragments of autolyzed, sequestrated liver tissue began to extrude along the drains. By the tenth postoperative day the patient was up in a chair, had begun to be ambulatory and to take a high protein, high caloric diet by mouth. The temperature curve continued to be irregularly elevated and a profuse, rancid drainage with numerous small fragments of autolyzed liver tissue continued in abundance. Penrose drains in the right posterosuperior subphrenic space were replaced by soft rubber tubes. The drains to other areas were gradually removed completely. It was then noticed that the rancid drainage was coming exclusively from the region in which the resection of liver tissue posterosuperior subphrenic abscess which was not being adequately drained by the rubber tubes which barely reached this pocket. Consequently, surgical drainage of this subphrenic abscess was accomplished at this time by resecting the entire twelfth rib and a portion of the eleventh rib on the right side, entering the right posterosuperior subphrenic space extraperitoneally. A large amount of rancid, necrotic pus was evacuated. The abscess was drained extensively with numerous Penrose drains and a large soft rubber catheter. During the next two weeks the Penrose drains were removed one by one, leaving in place the soft rubber catheter. Irrigations, at first of normal saline solution and later of freshly prepared Dakin's solution, were carried out daily through the catheter, and the steady closure of the abscess cavity was closely followed by means of repeated x-ray studies with instillation of iodized oil. The patient continued to improve and gain weight and was discharged from the hospital on July 3, 1947, sixty-four days after injury, in good physical condition and with a soft rubber catheter still in place in a small residual pocket in the right posterosuperior subphrenic space. Treatment continued with daily irrigations in the office as an outpatient and during the next ten days the small pocket in the subphrenic area closed completely and permanently. During the next five months the patient continued to gain in appetite, weight and strength; laboratory evidence of hepatocellular

damage as manifested by the cephalin-cholesterol flocculation test disappeared slowly but completely. He was able to return to light work at his plant eight months after injury. (Fig. 2.)

On January 10, 1948, the patient was subjected to a prolonged operative repair of a very extensive

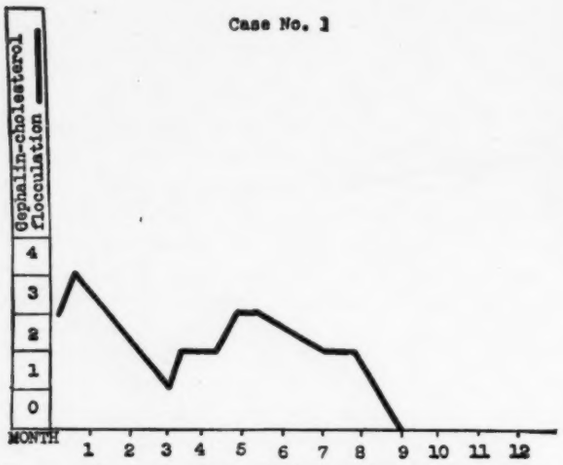

FIG. 2. Cephalin-cholesterol-flocculation test values (forty-eight hours) in Case 1 over a nine-month period following injury.

incisional hernia through an abdominal defect which extended beneath the twice repaired transverse incision of the initial operation. A meticulous repair occupying some two and one-half hours of operating time was done without any ill effects whatsoever and with an extremely smooth postoperative course. At no time did signs of hepatic insufficiency appear. Since June, 1948, the patient has been back at his old job as a welder doing a daily eight-hour stint of heavy work without undue fatigue or disability. One and one-half years after the repair of the incisional hernia the abdominal wall was very strong and well healed without any evidence of recurrence of the hernia or of any incisional weakness. (Figs. 3 and 4.)

CASE II. H. M., a sixteen year old white boy, was admitted to the surgical service of the Louisville General Hospital at 1:30 P.M., June 10, 1948. He had been injured when a jeep in which he was riding as a front seat passenger crashed under the rear end of a parked truck. The jeep's windshield was driven down pinning the patient against the seat. The impact of the windshield was against the lower thoracic cage of the patient.

The boy was unconscious on admission. Blood pressure was 70/30, pulse 140 and respiration 24 per minute. The scalp showed no external evidence of injury. The auditory canals were clear and the drums were normal. The pupils were dilated, the right greater than the left, but both reacted to light. At first there was deviation of the eyes to the left but this was soon replaced by gross nystagmus. There was ecchymosis of the left para-orbital

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FIG. 3. Patient two years after injury. Case 1.
FIG. 4. Side view patient two years after injury. Case 1.

region, with edema of the left eyelid. There was an extensive area of contusion over the sixth, seventh and eighth rib on the right side with a depression in the mid-clavicular line at the seventh right rib. Crepitation was present over this area. The heart sounds were faint but otherwise normal. Abdominal examination revealed splinting of the right upper abdominal quadrant. Rectal examination was negative. There were no injuries to the extremities and the reflexes were normal.

It was believed that the patient had cerebral concussion, fractures of the sixth, seventh and eighth ribs and possibly rupture of the liver. The red blood count on admission was 4,150,000, hemoglobin 12 Gm. and the white blood count 26,500. Plasma was administered to maintain blood pressure while typing and cross matching were being done. Repeated red blood count one hour after admission was 2,510,000. Red blood cells and an abdominal paracentesis in the right upper quadrant revealed fresh blood. A transfusion of whole blood was started and the patient was removed to the operating room for an exploratory laparotomy. Blood pressure was then 130/55 and pulse 110.

The abdomen was opened through a transverse upper abdominal incision. The abdominal cavity was filled with blood. This was removed by suction into an autotransfusion set and 1,500 cc. of the patient's blood were given back to him during the operative procedure. There was an extensive laceration in the right lobe of the liver from the peritoneal reflection over the mid-portion of the dome of the right lobe to the under surface of the liver. The laceration was about 5 inches deep. It appeared that the right lobe of the liver had been split in half. There was active hemorrhage from the wound which was controlled by packing with large abdominal pads while the abdomen was explored. No other intra-abdominal disorder was found. Compressed sheets of dry gelatin foam (gelfoam) were then placed in the liver laceration

and the liver was held together for ten minutes. The laceration was then observed for ten minutes while blood replacement continued and the blood pressure was maintained at a satisfactory level. No further bleeding was noted and the abdomen was closed in layers with interrupted silk sutures. The abdominal cavity was drained through a stab wound through which Penrose drains were placed to the pouch of Morrison over the dome of the liver and along the right lumbar gutter.

For the first eight postoperative days the patient did well. Vitamin K was given in 40 mg. doses daily; penicillin, 60,000 units, was given every three hours and streptomycin, 1 Gm. daily, was started on the tenth day. Choline chloride, 4 Gm., and methionine, 4 Gm. daily, were also given. Sodium bicarbonate was given to alkalinize the urine and to protect the kidneys against damage from the multiple transfusions. On the sixth day the red count and hemoglobin had dropped and the patient was given a transfusion. Clinically, he seemed much improved. Fluid developed in the right pleural space and was removed by thoracentesis on the eighth and tenth days. The prothrombin time remained within normal limits. On the eleventh day following a blood transfusion the red count was 4,200,000, with a hemoglobin of 10 Gm. During the next forty-eight hours the abdomen gradually became distended and on the thirteenth day the patient's condition changed rather rapidly. He went into shock and it was obvious that there was intra-abdominal hemorrhage. A transfusion was started by ankle vein and the patient was moved to the operating room. Blood was also transfused in an arm vein so that blood replacement could be rapid to control blood loss. To obtain adequate exposure of the dome of the liver the abdomen was opened through a right thoracico-abdominal incision. Of the dark clotted and unclotted blood, 1,500 to 2,000 cc. were removed from the abdominal cavity. There was a wide, gaping wound of the right lobe of the liver which contained necrotic, autolyzed liver. This was removed while rapid blood replacement maintained an adequate blood pressure. No bleeding could be found in the liver wound. The abdominal cavity was again explored and still no other source of hemorrhage could be found. The thoracico-abdominal wound was closed with drainage.

In the next twenty-four-hour period the patient was given 5,300 cc. of blood by continuous transfusion. The abdomen again became distended and paracentesis was necessary on two occasions, removing 1,400 and 1,000 cc. of bloody fluid. At times there was bright red blood on the wound dressing. The patient continued to bleed and on the twenty-first day, eight days after the second operation, he again went into severe shock and appeared to be dying. Blood was rapidly syringed into an ankle vein and the blood pressure was elevated to systolic 122, diastolic 68. It was believed that the only chance for survival was to find the source of the bleeding. He was taken to the operating room with blood transfusion as before and the thoracico-abdominal wound was reopened. From the large defect in the liver, necrotic liver was again removed

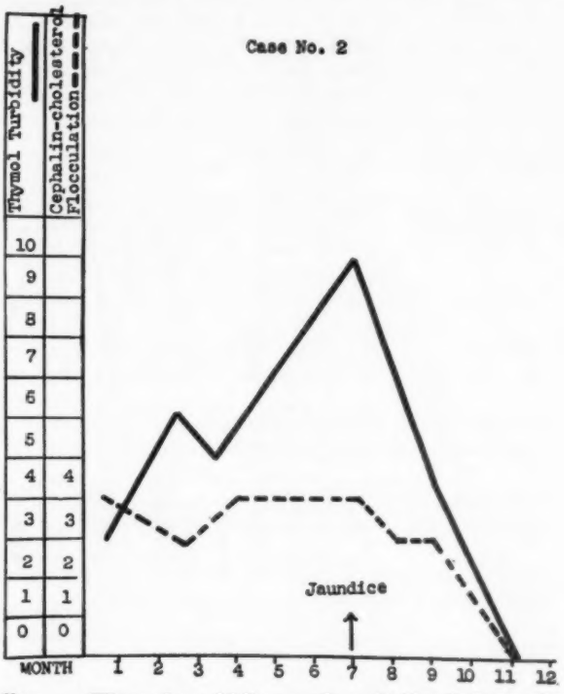

FIG. 5. Thymol turbidity and cephalin-cholesterol-flocculation test values (forty-eight hours) in Case 11 over an eleven-month period following injury.

in great quantity. The blood pressure had been elevated by rapid transfusion of 2,000 cc. of whole blood (blood pressure was 120/70 to 120/80) adequate to produce bleeding but no bleeding point could be demonstrated. The abdomen was carefully explored. It was thought that there might be bleeding from the splenic pedicle so the spleen was removed. The wound was closed by through-and-through sutures with drainage. For the next eight days the patient was kept alive by a continuous blood transfusion, receiving a total of 10,750 cc. of blood. The abdomen remained distended and seven days after the third operation the red blood count was 5,780,000 and hemoglobin 16 Gm. The patient then began to improve and to maintain a satisfactory blood picture although on the thirty-second day he became edematous and developed fluid in the left chest. Plasma protein was low at 5.9 mg. per cent. On the thirty-fourth day a large amount of bright red blood was observed on the wound dressing and the patient went into shock. Blood was rapidly syringed into and ankle vein and a continuous transfusion was kept running for the next forty-eight hours. After this episode there was apparently no liver hemor-

rhage of any consequence. The patient began to improve on about the thirty-eighth day, gaining weight and strength gradually. The cephalin-cholesterol flocculation and thymol turbidity tests indicated severe liver damage. (Figs. 5 and 6.)

The patient was discharged from the hospital on the 112th day following injury. Two months after discharge he developed jaundice, anorexia and vomiting and was readmitted to the hospital. On the medical service a diagnosis of homologous serum jaundice was made. Liver studies indicated no improvement in liver function; however, the prothrombin time was 88 per cent of normal. This patient remained in the hospital for the next four months and liver function studies showed gradual improvement, returning to normal eleven months after the injury. He regained his normal weight and strength. (Figs. 7 and 8.)

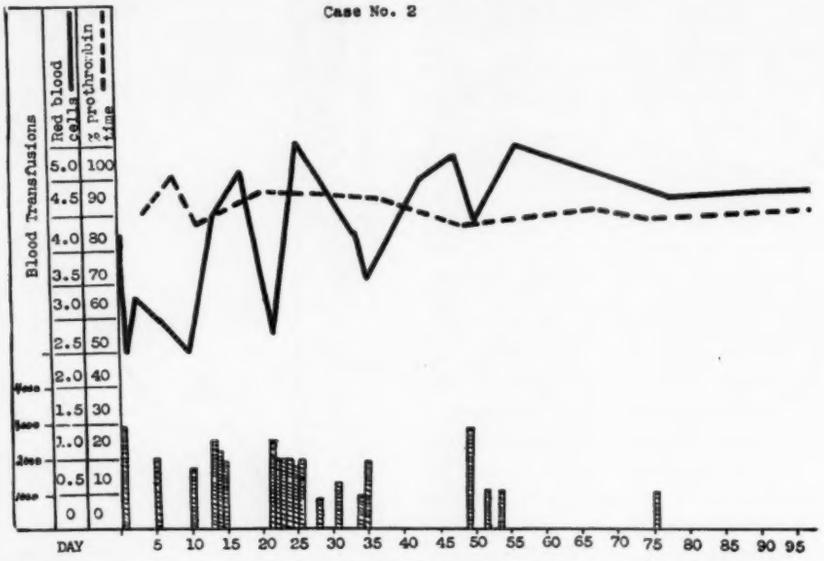

FIG. 6. Red blood count and prothrombin levels in Case II; whole blood transfusions indicated by cross-matched columns.

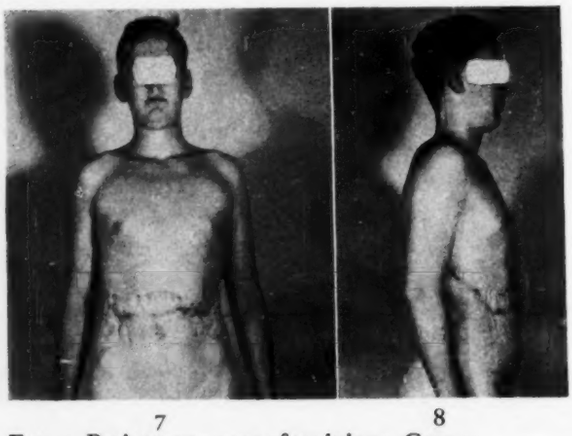

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FIG. 7. Patient one year after injury. Case II
FIG. 8. Side view patient one year after injury. Case II.

COMMENT

The efficacy of a non-suture technic of liver repair using sheets of oxidized cellulose (oxycel) or of gelatin foam (gelfoam) and manual compression was demonstrably impressive at the operating table in both cases.

In Case I the indications for and extent of débridement necessary were clear due to the presence of a large mass of almost completely amputated liver tissue plus extensive pulping of liver tissue which literally demanded removal. Because of the complete débridement of as much non-viable hepatic tissue as could be determined at the initial operation in this case, sequestration was minimal and secondary hemorrhage did not occur even though a massive wound disruption and extensive evisceration occurred on the third postoperative day.

In Case II repeated secondary hemorrhage was thought due to continuing sequestration of liver tissue resulting from the initial devitalizing contusion. In this case, as in similar cases in which a single cleft in the liver exists or presents without evidence of comminution or gross pulping, the indications and the necessity for operative débridement of liver tissue were not as clear cut.

It is also important to note that in the face of extensive hepatocellular damage indicated by the cephalin-cholesterol flocculation and thymol turbidity tests neither of these patients developed signs of the dreaded "hepatorenal syndrome." Also interesting is the fact that

normal or nearly normal prothrombin values were maintained in both cases without difficulty by large doses of synthetic vitamin K administered parenterally. This would seem to indicate a degree of hepatic reserve apparently belied by the other laboratory tests of hepatic function.[25]

The value of the thoracico-abdominal approach to lacerations extending over the dome of the liver, said to be the most frequent site of severe lacerations,[2] was well demonstrated in Case II, a long-waisted, hyposthenic individual with a high diaphragmatic vault. The use of autotransfusion in Case II without unfavorable reaction is to be noted.[24]

CONCLUSIONS

1. Massive hepatic rupture of the closed type is rare in civilian hospital practice and the hospital mortality in such cases is excessively high.

2. In extensively damaged livers suture repair is inefficient and control of hemorrhage difficult or impossible. As a consequence, the débridement of devitalized liver tissue is neglected entirely or inadequately performed.

3. Failure to débride damaged liver tissue adequately usually leads to autolysis and sequestration of hepatic tissue, secondary hemorrhage, sepsis, hepatorenal syndrome and death.

4. At the present stage of development of surgical technic improvement in the surgical management of hepatic rupture has been thwarted mainly by lack of an adequate technic for the control of hemorrhage from damaged hepatic tissue.

5. A non-suture technic employing gelatin sponge (gelfoam) or oxidized cellulose (oxycel) has been described which permitted fairly extensive débridement of damaged liver in one case and gave highly satisfactory immediate and late results in two cases.

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EXTENSIVE RESECTION OF THE SMALL INTESTINE*

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OCCASIONALLY a severe pathologic condition in the abdomen requires the removal of an extensive amount of small intestine. The problem may arise in emergency cases such as abdominal injury, volvulus and mesenteric thrombosis. It also may arise in patients with regional enteritis who have had repeated resections of small intestine and other chronic conditions. The extent of the resection is usually dictated by the pathologic condition encountered yet an understanding of the consequences of extensive resection is of great value to the surgeon at the time of operation as well as the internist who follows-up the patient later. It is hoped that our experience with two such cases and a third less extensive case in the past year and a half will be of interest to others.

CASE REPORTS

CASE 1. S. E. S., No. 265-750, a forty year old colored orderly at University Hospitals was seized with severe, crampy epigastric pain August 20, 1947. He had no nausea or vomiting and his bowel movements had been normal. It was a very warm day and the patient had been perspiring profusely while stacking mattresses. The patient had had two previous abdominal operations, namely, plication of a perforated duodenal ulcer eight years previously and a subtotal gastric resection for ulcer six months previously at another hospital. The first examination was one and a half hours after onset of pain.

On examination his temperature was 36.8°C., pulse 76, respiration 20 and blood pressure 118/68. He was a thin colored man soaked with perspiration complaining of epigastric pain. There was slight epigastric tenderness but no muscle spasm. Liver dullness was preserved; there was a well healed right upper rectus scar.

The patient was admitted to the hospital because of x-ray findings. Scout films of the abdomen showed no free gas under the diaphragm and no dilated loops of bowel. There was a small amount of gas in right abdomen thought to be in the cecum.

Normal saline was administered intravenously with very little change in pain. Six hours later the patient's temperature was 37.4°C., pulse 80, blood pressure 120/60 and white blood cells 13,700. At this time there was marked tenderness and muscle spasm in the right lower quadrant of the abdomen and also tenderness by rectal examination. Urinalysis was normal. In view of the signs of peritoneal irritation the patient was taken to surgery.

The patient was operated upon August 20, 1947. When the abdomen was opened through a right rectus incision, a foul odor and black loops of bowel were noted. It first appeared that the entire small intestine was gangrenous although not particularly dilated. When the gangrenous loops were eviscerated, a dense fibrous band ½ cm. in diameter was discovered running from the jejunum about 20 inches below the previous anastomosis with the stomach to the transverse colon. It was apparent on division of this band that almost the entire small intestine had herniated around it in a clockwise manner through 180 degrees with complete occlusion of the blood supply. There was complete gangrene of the bowel from a level 20 to 24 inches below the anastomosis with the stomach to a point 4 inches proximal to the ileocecal valve. Resection was carried out preserving all possible viable bowel and an end-to-end anastomosis was made just proximal to the cecum. The abdomen seemed nearly empty after resection, the loop being just of sufficient length to make the anastomosis.

During the course of the operation the blood pressure dropped to 80 mm. of mercury but with 1000 cc. of plasma and 500 cc. of whole blood the vital signs were surprisingly good at the close of the procedure.

The pathologic report on the surgical specimen was necrosis of jejunum and ileum, the segment measuring 16.6 feet (510 cm.).

The patient had a rather stormy postoperative course for eighteen days. Then, following drainage of a deep wound abscess, his temperature returned to normal. During the immediate postoperative period the patient was maintained on parental glucose, saline and amigen with added vitamins. A Levine tube was used intermittently during the first week. Liquid feedings were started in small amounts on the fourth postoperative day and were gradually increased. A high caloric, high protein and low fat diet was begun on the eight postoperative day. Protein hydrolysate was also given after

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meals. With the onset of oral feedings the patient developed four to seven liquid stools per day and noted the urge to defecate shortly after eating. Bismuth and paregoric drachms 11, A.C. seemed to be of slight benefit. Preoperatively the patient's usual weight was 58 Kg. On the nineteenth postoperative day he weighed 47.2 Kg. At the time of discharge September 19, 1947 (twenty-ninth postoperative day), he was having two to four semi-formed stools a day and seemed to be reaching an equilibrium.

However, the patient gradually lost weight on a high caloric, low fat diet and was readmitted to the Medical Service on October 9, 1947, three weeks later, because of four to ten liquid stools per day which were light yellow, foul smelling and foamy. His weight was 44.6 Kg. (98 pounds). He was unable to eat a full meal without the urge to defecate. However, smaller amounts of food such as a glass of milk could be taken without difficulty. His appetite was very good in spite of which he had become weak and malnourished.

The patient was kept under observation in the hospital until December 20, 1947. During this time studies were carried out with various diets, aluminum hydroxide, extract of belladonna and folic acid. Gradually the patient continued to lose weight and at the time of discharge four months following the operation he weighed 43 Kg. (95 pounds).

The patient was readmitted April 12, 1948. He complained of weakness, weight loss, inability to climb stairs and loss of libido. He was also having some pain in the left leg due to phlebitis. His weight was 40 Kg. (88 pounds) and he appeared extremely emaciated. He had learned to control his diarrhea partially by frequent small feedings and withholding fluids. He was still having two to four liquid stools per day. The patient became anemic and bedridden due to extreme weakness, developed edema of legs and face and fluid in his chest and finally died May 15, 1948, eight months and twenty-five days following operation. Autopsy was not obtained.

TABLE 1

LABORATORY FINDINGS, CASE 1

(SUBTOTAL GASTRIC RESECTION WITH THIRTY INCHES SMALL BOWEL REMAINING)

Date	Hemoglobin Per cent	Red Blood Cells	White Blood Cells	Urine	Plasma Protein	A/G Ratio	P	Blood Ca.	Blood Sugar	Blood Urea Nitrogen	Prothrombin Per cent	Cholesterol	V.K. Mg.	Folic Acid Mg. qd.	Weight kg.	Stools
8/20/47	Operation		.....	N	...	...	...	...	..	23.3	..	..	....	..	58	
8/25/47	76	4.2	.....	..	...	...	...	...	..	16.5	..	..	....	..	....	4–7
9/19/47	Discharge		.....	..	...	...	...	...	..	....	..	..	....	..	47.2	2–4
10/9/47	75	3.8	9,900	N	7.4	1.2	4.2	9.1	..	6	..	..	....	..	44.6	4–10
11/5/47	60	3.6	.....	..	6.2	1.1	3.1	8.5	..	....	..	..	....	30	42	2
11/10/47	..	....	.....	..	...	...	...	...	..	7.5	..	..	....	↓		
11/14/47	78	3.51	.....	..	...	...	3.7	9.3	59	....	18	..	20 t.i.d.	..	44.6	1
11/20/47	..	....	.....	..	...	...	...	...	..	....	..	..	↓	30		
11/29/47	78	4.6	.....	..	...	...	...	...	..	....	62	..		↓	43.3	2
12/2/47	75	...	.....	..	...	...	...	...	..	....	..	82			42.9	1
12/4/47	..	....	.....	..	...	...	...	...	..	....	..	..			43.7	2
12/8/47	..	....	.....	..	...	...	...	...	..	....	65	..	↓	..	41.8	1
12/13/47	..	....	.....	..	5.7	...	...	...	..	....	..	..	....	..	42.6	4
12/20/47	Discharge		.....	..	...	...	...	...	..	....	..	..	....	..	43	
12/27/47	62	3.1	10,000	N	...	...	...	...	..	....	40	..	....	..	....	1–2
1/6/48	60	3.5	.....	..	5.1	.9										
4/12/48	61	3.4	9,400	A+	4.7	...	...	6.9	..	....	..	..	....	..	40	2–4
4/21/48	52	2.4	6,400	N												
4/28/48	58	3.0	.....	N												
5/14/48	60	3.5	6,700	..	3.4	.9	...	...	..	4.5						
5/15/48	Expired															

The laboratory findings (Table 1) were as follows: oral glucose tolerance; fasting 55, one-half hour, 83; one hour, 92; two hours, 77; three hours, 80 and four hours, 64 mg. per cent with no sugar in urine. The Wassermann test was negative.

Comments. This patient had 24 to 30 inches of small bowel between the remaining portion of his stomach and his ileocecal valve. Approximately 12 per cent of his small bowel remained. The previous subtotal gastric resection had short circuited his duodenum and diminished the digestive action of his stomach. Food passed into the cecum a few minutes after being taken by mouth. Because of this the patient had diarrhea and severe weight loss of 18 Kg. and died literally of starvation, not being able to absorb adequate nourishment from the food taken by mouth.

Before death a rather marked hypochromic anemia developed, the plasma proteins fell to 3.4 Gm. per 100 cc. The blood urea nitrogen,

blood calcium and plasma cholesterol were all diminished. The glucose tolerance curve was very flat. The patient developed hypoprothrombinemia which responded to vitamin K administration by mouth. Various drugs to slow the passage time through the bowel were supervision. In order to produce variety and hence willingness on the part of the patient to take the full diet, three different food schedules for each study period were composed and administered on successive days. These schedules were as nearly identical as possible in protein,

TABLE II

STOOL ANALYSES CASE I WITH VARIOUS DIETS

Study Period	Diet (Three-day Total)			Stool Analysis (three-day collection)					
				Total Solid Gm.	Total Fat Gm.	Fat, Per cent Total Fecal Solid	Fat, Per cent Ingested Fat	Nitrogen Gm.	Nitrogen, Per cent Ingested Nitrogen
I	Proteins	Carbohydrates	Fat						
12–12 to 12–14 inclusive	57 (171)	211 (633)	104 (312)	267	186	70	59	12.3	45
II	Proteins	Carbohydrates	Fat						
1–1 to 1–3 inclusive	58 (174)	208 (624)	209 (627)	460	297	65	47	16.9	61
III	Proteins	Carbohydrates	Fat						
1–6 to 1–8 inclusive	59 (177)	406 (1,218)	107 (321)	200	91	45	28	8.2	29

not adequate. The patient tolerated a low fat, high carbohydrate diet better than others. Although the blood calcium fell to 6.9 mg. per cent, tetany did not develop.

Absorption Studies Case I. The results of fecal fat and nitrogen studies, carried out as described hereafter, are shown in Table II. Diets for individual study periods of five days were maintained constant. The first two days of each period stool specimens were discarded, the collections for analysis being begun at 8 A.M. on the third day. An attempt to mark the stools with charcoal was found impracticable because of their semi-liquid consistency. Collections were made in glass containers for seventy-two hours and immediately thereafter analyzed or refrigerated. A homogenous mixture of the seventy-two-hour specimen was prepared by suitable stirring and aliquots were examined for total solids, total fat and nitrogen. Solids were determined by drying in an oven for forty-eight hours. Total fat was performed by a modified method of Fowweather and nitrogen by the Kjeldahl method. Diets utilized in the study periods were carefully weighed and were consumed under constant carbohydrate and fat content as well as in mineral and water content. Diets were administered in six daily feedings all of which were as nearly equal as possible. Care was taken to see that the patient consumed all food placed before him. Extradietary water was maintained at as constant a figure as possible.

As can be seen from Table II the inability of this patient to metabolize normally both fat and protein is obvious. The ratio of total fat in the stools to both total solids and ingested fat is well above accepted normals. The increased loss in nitrogen is likewise evident. A comparison between study period I (dietary fat 312 Gm.) and study period II (dietary fat 627 Gm.) is of some interest. During the high fat regimen there was a substantial increase in total fecal solids, total fecal fat and to a somewhat less extent an increase in fecal nitrogen. Since ratios of fecal fat to the total fecal solids and ingested fat were not significantly changed, it seems that the principle effect of the high fat diet is concerned with increasing the bulk of the stool. Wolaeger et al.[1,2] in a series of studies upon normal persons found that there was no significant difference in the total fecal solids

when a diet of high fat (208 Gm.) and a diet of moderate fat (101 Gm.) content were administered. In these normal persons the amount of fecal fat as well as its ratio to total fecal solids was increased with the high fat intake. Interestingly, the fat content of the diets em-

TABLE III
CALORIC INTAKE AND LOSS CASE I WITH VARIOUS DIETS

Observation Period			Caloric Intake	Caloric Loss (Stools)	Available Calories
	I				
Proteins 171	Carbohydrates 633	Fat 312	6,024	1,982	4,042
	II				
Proteins 174	Carbohydrates 624	Fat 627	8,835	3,095	4,740
	III				
Proteins 174	Carbohydrates 1,218	Fat 321	8,457	870	7,587

ployed by these authors were roughly similar to that used in this patient in periods I and II. The difference between those normal people and this patient, therefore, seems in the latter instance to be the volume of stool passed under the influence of changes in dietary fat.

Observation period III was characterized by a diet similar in protein and fat content to the control (period I) but with a doubled carbohydrate content. As may be seen there was a lowering of fecal fat both in actual volume and in its relation to total fecal solids and ingested fat. There was an accompanying slight reduction in nitrogen loss. Explanation for these results is not clear and will require further amplification and clarification. Table III shows the caloric balance with respect to fecal loss for the three periods of observation. These figures are based upon the supposition that nitrogen loss in the stools is in the form of protein and that carbohydrate loss is negligible. Computations on this basis, therefore, represent the maximum in available calories. In observation periods I and II these obviously were deficient. The balance in period III more nearly approaches normal caloric requirements and would suggest that a diet of this general character might be the most advantageous in a patient of this sort.

CASE II. J. H. W., No. 271-092, a twenty-six year old white man, entered University Hospitals February 22, 1948, with abdominal cramps and vomiting of four days' duration. Seven previous operations had been performed elsewhere with three bowel resections for regional enteritis during the previous ten years. The last resection had been four years previously. The return of abdominal pain and diarrhea had occurred during the two months prior to admission with a weight loss of 20 pounds.

On examination the patient's temperature was 37.5°C., pulse 96, respiration 22 and blood pressure 114/54. His weight was 54.5 Kg. (120 pounds). He was thin and pale. His abdomen showed numerous broad scars. Moderate abdominal distention and visible peristalsis were present with borborygmi.

X-ray examination showed dilated small bowel loops. A Miller-Abbott tube met obstruction in the jejunum.

When the patient was operated upon March 4, 1948, extensive adhesions and a matted small bowel with greatly thickened wall were found. Obstruction was present in several places. Resection of an additional 115 cm. (3.8 feet) of jejunum was necessary and a jejunocolic anastomosis was carried out (18 inches jejunum remained later shown at autopsy).

The patient made a good recovery. There was diarrhea of five to thirteen liquid bowel movements per day with onset of feeding. There was gradual weight loss only slightly influenced by a high caloric, low fat diet, hydrolysed proteins and paregoric. At the patient's own request he was discharged April 3, 1948 (thirtieth postoperative day), having an average of five liquid bowel movements per day and weighing 44 Kg. (96.8 pounds).

The patient was readmitted to the Medical Service June 21, 1948, complaining of left flank pain, bloody urine, weakness and frequent bowel movements although he ate mostly starchy foods. He weighed 38.2 Kg., an additional loss of 6 Kg. during the two and a half months he was out of the hospital. After many cystoscopies, a left ureteral stone was removed surgically August 30, 1948. In spite of all dietary attempts and Tween-80,* as suggested by Jones et al.,[3] the patient gradually continued to lose strength and weight until he looked like a skin-covered skeleton. His last weight in December, 1948, was 33.7 Kg. He became bedridden about November 1st. His morale became very bad and he finally expired December 15, 1948, after an overdose of barbiturates which he had accumulated in his bed stand. Autopsy showed only 18 inches of jejunum remaining which was somewhat dilated but otherwise normal. The body was extremely emaciated and there was active tuberculosis without cavitation in the left lung.

* Polyoxyethylene sorbitan monooleate kindly supplied by Abbott Laboratories.

The laboratory findings (Table IV) were as follows: tuberculin 1/10,000 positive; duodenal contents showed normal proteolytic activity; oral glucose tolerance; fasting 94, one hour, 125; two hours, 93; three hours, 82; four hours, 80, with no sugar in urine; intravenous glucose tolerance; fasting 90, one hour, 161, with 2+ sugar in urine; two hours, 94; three hours, 66 and four hours, 65 mg. per cent. Blood smear taken on June 21st showed anisocytosis, poikylocytosis and hypochromia; platelets were increased. The differential count was as follows: segmented 51, unsegmented 13, lymphocytes 11, monocytes 9, eosinophiles 0, basophiles 1 and basket 15. On March 26, 1948, carmine dye passed per rectum two and a half hours after ingestion. Three day stool specimen collected September 10th showed the following: total solids 199 Gm., total fat 113 Gm. (57 per cent) and total nitrogen 11.4 Gm. (5.75 per cent).

TABLE IV

LABORATORY FINDINGS CASE II

(EIGHTEEN INCHES JEJUNUM AND ELEVEN INCHES DUODENUM REMAINING)

Date	Hemoglobin Per cent	Red Blood Cells	White Blood Cells	Urine	Serum Protein Gm.	A/G	Serum Ca. Mg.	P	Blood Sugar	Blood Urea Nitrogen Mg.	Prothrombin	Chlorides Mg. Per cent	MPT	Uric Acid Mg.	T-80 t.i.d.	Pancreatic ex. b.i.d.	Weight kg.	Stools
2/22/48	95	4.7	6.8	N	6.4	...	...	...	..	10.5	..	571	neg.	..	...	...	54.5	
3/4/48	Resection small bowel																	
o.p.																		
3/16/48	80	4.05	....	N	...	...	...	...	94	...	82	...	...	..	...	...	47.3	12
4/3/48	Discharge				...	...	...	...	..	....	..	...	...	..	...	...	44	4
6/21/48	85	4.3	8.1	RBC	6.1	1.4	...	...	..	12	..	570	...	..	...	...	38.2	5
7/7/48	88	4.3	....	RBC	...	...	...	...	..	6.8	..	576	...	..	...	...	40.2	1
7/16/48	..	....	....	RBC	5.3	1.8	7.2	...	..	....	..	...	...	..	...	...	41.2	2
7/24/48	..	....	....	RBC	...	...	9.2	3.7	..	....	..	...	...	4	...	...	37.6	4
7/29/48	65	3.2	8.25	N	5.9	...	...	...	..	12	..	530	...	..	...	...	34.5	2
8/6/48	78	3.03	6.0															
8/16/48	80	....	6.5	N	6.2	1.1	...	...	..	15.8	..	...	...	..	...	...	35	1
8/24/48	85	....	....	....	...	...	...	...	..	9.0	..	558	...	..	...	...	34.8	1
8/30/48	Left ureterotomy																	
9/2/48	..	....	....	WBC	...	...	...	...	..	7.5	..	...	...	..	...	...	31.7	3
9/7/48	70	3.81	6.8	WBC	...	...	...	...	..	....	..	...	...	..	...	...	31.6	5
9/9/48	..	....	....	....	...	...	...	...	..	....	..	...	...	..	3.3			
10/12/48	75	2.78	3.8	WBC	...	...	...	...	..	....	..	...	...	..	↓	2.5	31.2	2
11/15/48	53	2.24	3.8	N	5.3	1.7	...	...	..	....	..	607	...	..		↓	33.2	2
12/10/48	50	2.4	3.2	....	...	...	...	...	..	....	..	...	...	..				
12/15/48	Patient expired				...	...	...	...	..	....	..	...	...	..				

Comments. This twenty-six year old man had all but 18 inches of his jejunum removed in successive stages due to regional enteritis. The duodenum was 11 inches long giving a total of 29 inches of small bowel between the stomach and colon. With this he maintained life for nine months. Similar to Case 1 there was diarrhea and extreme loss of weight (21 Kg.) and strength before death. Although the diarrhea was controlled to some extent by diet and drugs, the stools remained quite bulky and contained a large amount of fat (57 per cent).

The patient developed hypochromic anemia and diminution of plasma proteins. He did have urinary bleeding due to his ureteral stone but this was controlled by blood transfusions and ureterotomy three and a half months before death. The blood calcium dropped to 7.2 mg. and this rose to 9.2 with the administration of calcium gluconate orally.

CASE III. E. J. G., No. 186-016, a thirty-two year old colored man, was readmitted to University Hospitals May 12, 1948, two hours after discharge, because of epigastric pain, vomiting and diarrhea. He had spent the previous two weeks in the hospital because of pain in the left chest and a pericardial friction rub which had been diagnosed acute pericarditis subsided with bed rest.

On examination his temperature was 36.9°C., pulse 88, respiration 20 and blood pressure 126/88. His weight was 75 Kg. (166 pounds). There was tenderness in the right upper quadrant of the abdomen with some involuntary muscle spasm. The lower abdomen was completely normal. White blood cells were 9,000.

The pain continued in the abdomen and became more severe. On May 14, 1948, his temperature was 39.5°C., pulse 90; respiration 24, blood pressure 110/70 and white blood cells 18,700. There was diffuse tenderness and spasm most marked in the lower abdomen. The diagnosis was acute peritonitis.

The operative findings on May 14, 1948, were as follows: gangrene of terminal ileum, cecum and

TABLE V

LABORATORY FINDINGS CASE III

(RESECTION 5.5 FEET TERMINAL ILEUM AND RIGHT HALF OF COLON)

Date	Hemoglobin Per cent	Red Blood Cells	White Blood Cells	Urine	Serum Protein Gm.	A/G Ratio	P	Ca.	Blood Urea Nitrogen Mg.	Cholesterol	Folic Acid t.i.d.	T-80 Gm. t.i.d.	Weight Kg.	Stools Per Day
4/27/48	90	4.84	8,300	N	...	....	...	...	9	...	....	...	75	1
5/12/48														
5/14/48														
o.p.														
5/15/48	85	4.84												
5/17/48														
5/18/48	85	4.7												
5/19/48	..	....	.....	..	...	....	...	...	...	...	....	...	....	3
5/25/48	75	4.38	.....	..	...	....	...	...	...	...	....	...	....	4
5/28/48	73	....	.....	..	6.6	1.4	...	...	...	...	....	...	61.3	8
7/27/48	80	4.4	6,100	..	6.3	1.6	...	...	7.5	...	....	...	59.6	3
7/30/48	..	....	.....	..	...	....	...	...	...	97	....	...	....	1
8/12/48	..	....	.....	N	...	....	...	...	...	...	.015	...	....	2
8/16/48	..	4.07	4,100	..	7.3	1.2	...	...	...	...	↓	...	....	2
8/20/48	66	3.71	.....	N	...	....	...	...	...	...	↓	...	60.4	2
8/25/48	..	....	.....	..	...	....	...	...	...	...	↓	4.5		
8/26/48	..	....	.....	..	6.5	1.03	3.6	9.5	...	69	↓	↓	60.6	1
9/3/48	..	....	.....	..	6.8	1.4	...	...	...	109	↓	↓	....	1
9/12/48	..	....	.....	N	...	...	...	...	...	...	↓	9.9		
9/17/48	70	....	3,950	..	6.5	1.5	...	...	...	110	↓	↓	59.2	1
9/28/48	70	4.08	3,700	..	...	....	...	...	...	121	↓	↓	58.8	1
10/2/48	Discharge		.....	..	...	....	...	...	...	...	....			

TABLE VI

STOOL ANALYSES CASE III WITH FOLIC ACID AND TWEEN-80

Study Period	Diet			Medication	Stool Analysis (3 day collection)					
	Three-day Total				Total Solids Gm.	Total Fat Gm.	Fat, Per cent of Total Fecal Solids	Fat, Per cent Ingested Fat	Nitrogen Gm.	Nitrogen, Per cent Ingested N.
	P	C	F							
I 8–8 to 8–10 inclusive	255	867	225	None	227	128	56	59		
II 8–16 to 8–18 inclusive	259	861	228	Folic acid .015 Gm. q.d.	174	100	58	44		
III 8–26 to 8–28	257	842	216	Folic acid .015 Gm. q.d. Tween-80 4.5 Gm. q.d.	222	130	60	60		
IV 8–31 to 9–2 inclusive	263	893	229	Folic acid .015 Gm. q.d. Tween-80 4.5 Gm. q.d.	200	104	50	45		
V 9–24 to 9–26 inclusive	247	803	225	Folic acid .015 Gm. q.d. Tween-80 9.9 Gm. q.d.	236	119	51	53	9.9	25

ascending colon due to mesenteric thrombosis. One hundred sixty-five cm. (5.5 feet) terminal ileum plus right half of colon removed and bowel anastomosed, upper ileum to transverse colon.

The patient made a satisfactory postoperative recovery. Anticoagulants were administered for ten days. Diarrhea consisting of four to eight liquid stools per day was partially controlled with high caloric, low residue diet and paregoric. The patient was discharged on his twenty-fourth postoperative day weighing 61.3 Kg. and having three to four loose stools per day.

The patient was readmitted July 27, 1948, to the Medical Service because of thrombophlebitis of the left leg. He also complained of three to five loose stools per day and weight loss. He was treated with bed rest, heparin and dicumarol with improvement of the thrombophlebitis. The patient was discharged October 2, 1948, weighing 58.8 Kg. and having one to two soft voluminous stools per day. He was reported to be getting along satisfactorily one year after operation.

The laboratory findings (Table v) were as follows: gastric analysis showed no free hydrochloric acid; duodenal contents showed normal pancreatic activity; oral glucose tolerance test September 28, 1949; fasting 86, one-half hour, 126; one hour, 124; two hours, 87; three hours, 85 and four hours, 73 mg. per cent. Intravenous glucose tolerance test September 18, 1948; fasting 74, one-half hour, 128 and one hour, 116 mg. per cent. Vitamin A tolerance test; fasting 1 unit; one hour, 1 unit. The blood Wassermann test was negative.

Comments. This thirty-two year old colored man is of particular interest because of rather severe digestive disturbances following resection of a relatively short segment of terminal ileum (5.5 feet) with the right half of the colon. Pancreatic enzymes in the duodenal secretions showed normal activity. The transit time of food was one hour from mouth to transverse colon. Diarrhea in this case was fairly well controlled by drugs and low fat, high carbohydrate diet. However, the patient lost 16 Kg. during the first five months after operation and developed a mild anemia and lowered blood cholesterol.

Metabolic studies on this patient are summarized in Table VI. Observation periods, methods of diet administration, stool collections and stool analyses were carried out as in Case 1. The diet was maintained constant throughout all five observation periods, the difference between the periods being only in the medication administered. Folic acid was given in one dose in the morning before the first feeding. In period III Tween-80 was administered in three equally divided doses after morning, midday and evening feedings whereas in period IV it was given in the same fashion but before the same feedings. In period V Tween-80 was given in the same manner as in period IV except the amount was doubled. As may be seen there was no significant alteration in fat absorption when this patient was given folic acid alone or with Tween-80. Jones, Culver, Drummey and Ryan[3] administered Tween-80 to a selected group of patients showing defective fat absorption following subtotal gastrectomy and to persons with sprue, ileitis and pancreatic fibrosis. They were of the opinion that this material increased vitamin A absorption in these people. In further studies upon malnourished persons following subtotal gastrectomy they were of the additional opinion that Tween-80 lowered the total fecal fat and fecal percentage of ingested fat in these patients. It may be that the lack of effect of this substance in this patient is concerned with the reduction of absorptive area as a result of the bowel resection. Substantiating a lack of effect from Tween-80 in this patient was his failure to gain weight during its administration for one month. It is of interest to note that both in this patient and patient II there was a fall in the total leukocyte count during the administration of Tween-80.

HOW MUCH SMALL BOWEL MAY BE REMOVED

Senn in 1888 was of the opinion that one-third of the small intestine (200 cm. or 6½ feet) could be removed without serious nutritional disturbance to the individual. Haymond[4] in reviewing the literature in 1935 collected 257 cases in which 200 cm. or more small bowel was removed for various reasons. The over-all operative mortality was 33.5 per cent which he thought was probably not a true figure since unsuccessful cases tend not to be reported in the literature. Of the survivors 36.7 per cent were reported to have done well. Taking 657 cm. (21.9 feet) as the average length of the small bowel, there were eighty-six cases with good results in which the patient had an average of 47.2 per cent of the small intestine removed. There were twenty-one cases with fair results in which an average of 55.8 per cent was removed and fifteen cases with poor results in which an average of 52.9 per cent was removed. This author concluded that 50 per

cent removal of the small intestine constitutes the upper limit of safety.

Successful cases have been reported in the recent literature[5–9] in which the remaining segment of jejunum was 3½ feet or less in length. The patient studied by West[7] had repeated bouts of tetany due to low blood calcium. Further studies are reported on this case by Todd et al.[10] The other cases were apparently without significant digestive difficulties five to seven months after operation. Longer follow-up reports on these cases would be of interest.

Other recent cases of successful extensive resection of small intestine have been reported.[11–20] Washburn[23] reports the case of Jerauld and Washburn[22] in which the patient is alive and doing satisfactorily twenty-two years after removal of approximately two-thirds of the jejunum and ileum.

Jensenius[21] observed that resection of the distal two-thirds of the small bowel in fifteen dogs lead to death in an average of 144 days. Three of five animals with resection of the proximal two-thirds of the small intestine, on the other hand, were unaffected by the resection while the other two died 91 and 118 days later. Impairment of fat absorption, diarrhea and shortening of the transit time of bowel contents were much less marked in animals with the proximal portion of the small bowel removed than in animals with the distal portion of the small bowel resected. He concluded that resection of the jejunum caused less physiologic disturbance than resection of the ileum. This work throws an interesting light on the problem of small bowel resection in that not only the length of the resection is important but also the level of the resection.

In regard to our first and second cases reported herein these men each had approximately 88 per cent of their small bowel removed. They made a good postoperative recovery but died of inanition approximately nine months later. These patients each had the distal portions of their small bowel removed. Case II is of further interest in that prior to our resection he had six feet of small bowel (approximately 27 per cent) between pyloris and colon and had lived comfortably for four years until recurrence of regional enteritis occurred. He was able to live satisfactorily with slightly less than one-third of his small bowel but died of inanition when an additional 3.8 feet was removed. It should be noted that this man's intestine had been removed in successive stages over a period of years.

Case III on the other hand demonstrates serious metabolic disturbance following removal of approximately 25 per cent of the small bowel along with the right colon.

It appears from our experience and from that of others in the literature that the response to resection of the small bowel is quite variable. Many factors such as health, age of the patient and health of the remaining segment of the intestine are important. It also appears that distal resections of the small bowel are less well tolerated than proximal resections.

It appears in general that resections of 30 to 50 per cent are usually well tolerated and also that many patients do satisfactorily with greater percentages removed.

SUMMARY

Two cases of extensive small bowel resection (approximately 88 per cent) are reported. These patients had severe diarrhea, excessive fat in the stools, weight loss and anemia and died of inanition approximately nine months after operation.

A third case is reported in which the patient had severe digestive disturbance following removal of 5.5 feet of terminal ileum (approximately 25 per cent of the small bowel) and the right colon for mesenteric thrombosis.

The effect of various drugs and diets determined by metabolic experiments are reported in two of the cases. Case I showed a diminution in stool volume and fat content with a high carbohydrate, low fat diet substantiating the idea that these patients do best with this type of diet. Folic acid and Tween-80 did not significantly alter the fat absorption in Case III.

CONCLUSIONS

The response of patients to removal of extensive amounts of small intestine is quite variable.

Although two of our patients died of inanition nine months after removal of approximately 88 per cent of the small bowel, one of these had lived comfortably for four years prior to our operation with approximately 73 per cent of his small intestine resected.

Appreciation is expressed to Dr. John H. Grindlay for making available to us the work

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MANAGEMENT OF RUPTURE OF THE DUODENUM DUE TO VIOLENCE*

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RUPTURE of the duodenum from non-penetrating violence creates a distinct diagnostic and clinical problem requiring considerable judgment for proper surgical management. The increasing number of injuries, particularly those resulting from automobile accidents, will unquestionably increase the frequency of these cases. A review of the literature[1–28] reveals that many reports have dealt with the subject of perforation of the gastrointestinal tract from both non-penetrating and penetrating injuries. From these clinical surveys one realizes that non-penetrating (subcutaneous) rupture of the intra-abdominal viscera occurs commonly and more frequently than most clinicians suspect. In a statistical analysis of reported cases up to 1935 Counseller and McCormack[26] found that 1,183 subcutaneous ruptures of the intestines occurred without evidence of penetrating injury to the abdominal cavity. In this group of patients there were 113 with subcutaneous ruptures of the duodenum, about 10 per cent of all gastrointestinal ruptures from non-penetrating injury. The majority of authors has pointed out the difficulty in obtaining an adequate history, particularly when these patients are in a state of severe peripheral circulatory collapse. Moreover, they have stressed the fact that there are no pathognomonic signs which indicate the diagnosis of traumatic rupture in any specific part of the gastrointestinal tract. All observers have agreed that complicating involvement of other intra-abdominal organs such as the liver, spleen, pancreas, kidneys and the bladder tends to confuse the clinical picture so that an accurate diagnostic approach cannot be outlined. Injury to other parts of the body, particularly to the head and chest as well as the thoracic and lumbar spines, may overshadow and minimize any abdominal disorder.

Specific papers dealing with the subject of subcutaneous perforation of the duodenum have appeared sporadically over a period of many years. Continental observers have written about this lesion and in America numerous observers have recorded occasional cases with clinical observations and impressions.[29–40]

Almost nothing has been written during the past twenty years about rupture of the duodenum due to non-penetrating violence. Of interest is the fact that the mortality rate from such a rupture has been placed in the vicinity of 90 per cent. The purpose of this discussion is to review the types of rupture of the duodenum due to violence, to correlate the history and physical findings with roentgenographic evidence of perforation and to report four of our own cases. In two cases the diagnosis was made preoperatively while in the remaining two cases the diagnosis was established after complications suggested further study.

GENERAL CONSIDERATIONS

Rupture of any part of the gastrointestinal tract, particularly the duodenum by action of blunt force with little or no injury to the abdominal wall, is one of the most interesting subjects in the whole field of traumatic surgery. Clinicians working in the field of trauma must be constantly aware of the possibility of subcutaneous rupture of the duodenum when attempting to evaluate intra-abdominal injury. On the other hand, to those who are not familiar with traumatology of this region the possibility of intraperitoneal or extraperitoneal rupture of the duodenum is usually not considered. In the presence of non-penetrating injury to the abdominal wall one should teach the danger of rupture to all fixed intra-abdominal organs, particularly the liver, spleen, kidneys and the fixed portions of the gastrointestinal tract.

History. The history of trauma to the abdomen by blunt force regardless of type should

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direct the attention of the clinician to the possibility of a fracture of the duodenum. The injury may result from the patient's having been crushed between heavy objects, struck on the abdominal wall by a blunt force, run over by some type of vehicle or having been kicked directly in the abdomen. Automobile accidents may predispose to this lesion because many drivers are prone to trauma of the anterior abdominal wall, particularly in the region of the epigastrium, when they are forcibly shoved forward against the steering wheel. If the injury has been confined to the abdominal wall, the patient should relate an accurate description of the accident. However, many patients have associated injuries such as trauma to the thorax or the head and their condition precludes an accurate history.

Physical Findings. Non-penetrating rupture of the duodenum affords the physical findings of spontaneous or penetrating rupture of any hollow viscus in the abdominal cavity. There is usually evidence of peritoneal irritation whether the rupture is intraperitoneal or extraperitoneal. Certain findings are suspicious even though not pathognomonic of this injury.

1. Pain is usually a characteristic feature of non-penetrating rupture of the duodenum. Pain, for the most part localized in the epigastric region, may oscillate between the right and left hypochondriac regions. In some instances pain is said to be intense, severe and located deep in the abdominal cavity. In other cases the pain may occur characteristically in the posterior region of the upper abdomen and localize over the upper lumbar vertebral region. In cases of intraperitoneal rupture of the duodenum pain may be diffuse over the entire abdomen because of a generalized peritonitis which is at first chemical and later bacterial. Conversely, extraperitoneal rupture of the duodenum may not reveal such diffuse pain because there is less intraperitoneal irritation. In such instances pain may be localized to the lower thoracic and upper lumbar regions posteriorly.

2. Abdominal rigidity, usually an indication of peritoneal irritation, is characteristic of rupture of the duodenum due to violence and the degree of rigidity found depends upon the time of examination after injury. In the intraperitoneal rupture one would expect greater rigidity of the anterior abdominal wall than in the extraperitoneal variety.

3. Localized tenderness may be found in the epigastric region suggesting the possibility of injury to the stomach or duodenum. Persistence of localized tenderness is frequently helpful in directing the surgical approach when operation is contemplated.

4. Nausea and vomiting may be associated with traumatic rupture of the duodenum and the degree of either of these clinical features will depend upon many factors. Recently ingested food predisposes to nausea and vomiting; with large rents in the duodenum copious amounts of duodenal secretion promptly escape into the peritoneal cavity initiating reflex vomiting.

5. Hypoactive peristalsis or absence of peristalsis indicates peritoneal irritation and suggests peritonitis.

6. Obliteration of liver dullness suggests the presence of a rapidly produced pneumoperitoneum such as results only from a rupture of a hollow viscus. Pneumoperitoneum can be confirmed in a large percentage of cases roentgenographically. Intraperitoneal rupture of the duodenum due to trauma can explain the source of air. In extraperitoneal rupture of the duodenum the presence of air about the right kidney by roentgenographic evidence may be diagnostic of this condition as pointed out by Sperling and Rigler.[39]

7. Pain in the testicles may be a sign of irritation in the retroperitoneal tissues by involvement of their nerve supply. When this sign is observed in patients who have sustained non-penetrating injury to the anterior abdominal wall, the clinician should consider extraperitoneal rupture of the duodenum. The significance of this observation was discussed by Butler and Carlson.[35]

8. The presence of air or gas in the pelvic tissues may indicate a tear of a retroperitoneal hollow organ. The duodenum is the most important hollow viscus subject to rupture and capable of allowing escape of air to the pelvic tissues.[35]

9. The physical findings of an intraperitoneal or an extraperitoneal abscess may be a cardinal sign in cases in which non-penetrating rupture of the duodenum has occurred many hours or even days previous to the initial physical examination. In one of our patients a retroperitoneal abscess which had existed for many weeks presented in the right lower quadrant. When a history of severe trauma is elicited in the presence of an unexplained abscess, rupture of the duodenum should be considered.

In another of our cases the physical findings soon after an episode of trauma were prominent in the right lower quadrant and led to the diagnosis of appendicitis. Discoloration and edema of the peritoneum indicated inflammation in the retroperitoneal space. Exploration of this area revealed clear, watery fluid suggestive of high duodenal content.

The degree of peripheral circulatory collapse and the clinical observations of temperature, pulse, respirations and blood pressure will help considerably in the evaluation of the patient's condition at any given time. They are not particularly significant in establishing the diagnosis of traumatic rupture of the duodenum.

Laboratory Findings. Clinical laboratory determinations may help to eliminate certain conditions and to establish the correct diagnosis of traumatic rupture of the duodenum, Leukocytosis is usually found in these cases and it may vary between the limits of 10,000 to 40,000 white blood cells. A low or falling red blood count and hemoglobin determination may indicate the degree of bleeding from such a rupture of the duodenum.

Because of the location and intensity of the pain associated with all of the other physical findings which have been mentioned, the consideration of traumatic pancreatitis should justify the determination of blood serum amylase. In some instances the blood amylase may be elevated either in conjunction with a rupture of the duodenum or due to traumatic pancreatitis alone.

Roentgenograms of the gastrointestinal tract are much more significant than any other laboratory procedure available to us at the present time. We have not been reluctant to visualize the stomach and duodenum following the technic of Hampton. Either lipiodol or thin barium sulfate may be used. In intraperitoneal rupture of the duodenum a definite sinus may be visualized and the diagnosis in this location may be demonstrated clearly. In the case of extraperitoneal rupture of the duodenum the roentgenogram taken either in the oblique or lateral position may demonstrate a sinus leading from the duodenal lumen to the retroperitoneal space. As mentioned, preliminary films of the abdomen may demonstrate a pneumoperitoneum suggesting the possibility of a ruptured hollow viscus which could result from intraperitoneal rupture of the duodenum. As pointed out by Sperling and Rigler, collection of air about the right kidney usually suggests extraperitoneal rupture of the duodenum. These differential features of the roentgenographic survey should help immeasurably in making a more positive diagnosis of non-penetrating traumatic rupture of the duodenum.

DIAGNOSIS

Diagnosis of rupture of the duodenum due to violence is not always easy to establish preoperatively. From reported cases in the literature the rupture in the duodenum is not always found at operation. Clinical evaluation of the nature, type, location, extent and severity of the injury should always predispose to the assumption that intra-abdominal viscera have been injured.

Fracture of the liver is not particularly frequent and usually the findings are limited early to pain, abdominal rigidity, evidences of peritoneal irritation and localized tenderness in the right upper quadrant. This is not always true because there have been large fractures of the liver in which hemorrhage and biliary secretions into the peritoneal cavity were profuse, creating generalized abdominal signs and symptoms.

Rupture of the spleen frequently points to findings in the left hypochondriac region. The characteristic features of a ruptured spleen are: hemoperitoneum with diminished peristalsis, mild abdominal distention, pain in the left hypochondrium, elevation of the left diaphragm, a dull percussion note over the splenic region, pain in the left supraclavicular region, and often shock disproportionate to the abdominal findings because of rapid blood loss. The classical cases of ruptured spleen are not particularly difficult to diagnose but there are many cases which do not fall into this group.

Acute traumatic pancreatitis can only be diagnosed positively on the basis of an elevated blood serum amylase. The signs and symptoms of epigastric pain, local tenderness in this region, nausea and vomiting, and a state of collapse out of proportion to the physical findings should always make one consider the possibility of traumatic pancreatitis. Because the pancreas lies in close proximity to the duodenum, a traumatic rupture of the latter can occur concomitantly with acute traumatic pancreatitis. In one of our cases this combination of associated injury was noted.

Acute appendicitis is another possible diagnosis which must be differentiated from

traumatic rupture of the duodenum. We have seen cases of acute appendicitis associated with trauma to the anterior abdominal wall. In intraperitoneal rupture of the duodenum, gastric, duodenal, biliary and pancreatic secretions traverse the peritoneal cavity by flowing inferiorly across the right gutter. This fact explains symptoms and signs localized to the right lower quadrant. This point was clearly demonstrated in one of our cases and an appendectomy was performed before the correct diagnosis was made.

Fractured kidney is not particularly difficult to differentiate from rupture of the duodenum. The presence of blood in the urine usually confirms this diagnosis. Physical findings referable to the kidneys will suggest the correct diagnosis.

Subcutaneous perforation of the jejunum and ileum, either alone or in conjunction with traumatic rupture of the duodenum, would be difficult to diagnose. Obviously such perforations would create peritoneal irritation and in most instances a pneumoperitoneum. The other characteristic findings of intraperitoneal involvement should be present and consideration of injury to these organs would indicate the necessity of doing an exploratory operative procedure.

There are other conditions associated with trauma to the abdominal wall which have not been mentioned in this differential diagnostic scheme but those mentioned are the most important. In summary it may be said that if the surgeon will keep in mind the possible injuries to the various intraabdominal organs, chiefly fractures of the viscera, the possibility of rupture of the duodenum due to violence will not escape his attention.

TREATMENT

Preoperative. Management of non-penetrating rupture of the duodenum may be considered to offer a better prognosis than formerly. The treatment of shock, availability of blood and blood substitutes, continuous gastric aspiration and chemotherapy are only a few of the many factors influencing the mortality rate.

The patient should be put at bed rest and all oral intake should be discontinued. It is important to treat any degree of peripheral circulatory collapse which the patient may demonstrate on admission to the hospital. One may question the advisability of giving any sedative to these patients in the early course of their illness; although if they are suffering intense pain, certainly demerol should be administered. The rationale in using demerol is based upon the fact that it has an atropine-like action and therefore diminishes gastric secretions. Demerol in sufficient dosage will control pain which may not be helped by the administration of morphine. Water and electrolyte balance should be maintained by the parenteral route. Blood and blood substitutes should be instituted early in the treatment of these cases and the administration of these substances should be based upon the indications and requirements. All clinical laboratory data should be recorded as a base line for the progress and course of the patient. Chemotherapy should be administered early following injury. There is no unanimity of opinion about the types of chemotherapeutic agents to be used. Because there is no knowledge of the type of organisms present either in the peritoneal cavity or in the extraperitoneal spaces, a "gunshot" method of administration must be used. Penicillin at the rate of 300,000 units per day should be given. In our opinion streptomycin should also be administered; this is given at the rate of 0.5 Gm. twice daily. Intravenous sulfadiazine may be given; and if it is used, a blood level of between 8 and 12 mg. per cent should be maintained.

These patients should be observed frequently for two to eight hours and careful notes recorded as to the physical findings in the abdomen at various intervals. We believe that these patients need not be rushed to the operating room for immediate exploratory laparotomy as advised by some observers. If the patient's condition is satisfactory, if the state of peripheral circulatory collapse has been corrected and if the tentative diagnosis has been established, unquestionably operation can be done without delay. Usually these conditions are not encountered. In our experience with continuous gastric aspiration and general supportive measures including chemotherapy, the condition of the patient improves permitting a more accurate diagnosis. This may require twenty-four hours or more. In those instances when there is associated injury to other abdominal viscera, the possibility of selecting an optimum time for operation is enhanced. The correct diagnosis is usually made by roentgenographic studies which require time. Once the diagnosis of a ruptured duodenum, either intra- or extraperitoneal, has been made, operation should be performed. At the time of

exploration the patient must have supportive therapy and whole blood should be available.

Operative. Exploration of the abdominal cavity should assure the surgeon that no pathologic lesion has been overlooked. Intraperitoneal rupture of the duodenum should be demonstrated without much difficulty. In our experience the rents have occurred at the junction of the second and third portions of the duodenum. The edges of the tear are usually irregular and there has been considerable edema in the duodenal wall. Adequate surgical repair is based upon good approximation of the mucosal surface using a Connell suture of continuous gastrointestinal No. 000 chromic catgut. The muscular and serosal coats of the duodenum are reinforced with either interrupted sutures of silk or the Halsted mattress sutures of medium silk. In any instance the reinforcement layer is important and must be properly placed and adequate to support the initial catgut suture in the inner mucosa. The use of drainage depends on the degree of infection and the amount of devitalized tissue in the region. Cigarette drains are used and we advise that they be brought out from the peritoneal cavity through a stab wound rather than through the working incision.

In the case of extraperitoneal rupture of the duodenum the operative treatment is somewhat different and therefore warrants some explanation. In this instance the rent in the duodenum is not clearly seen and is frequently diagnosed by the presence of a hematoma in the base of the mesocolon. The duodenum may be edematous and discolored by the presence of a retroperitoneal clot or collection of bloody fluid. The duodenum is mobilized and explored by incising the posterior parietal peritoneum along the right lateral border of that organ. This is an avascular area and there is slight change of damaging any major structures. The duodenum may be mobilized toward the left gutter and the rupture easily demonstrated. The same type of operative repair is advocated and the retroperitoneal area is always drained. Emphasis is placed on the possibility of rupture of the fourth portion of the duodenum. This is the most difficult portion to explore in a retroperitoneal fashion and, therefore, care must be taken not to damage major vessels, particularly the superior mesenteric and middle colic arteries.

The combination of intraperitoneal and extraperitoneal rupture of the duodenum can occur and such cases have been reported. This, however, does not change the operative technic for closure and simply indicates that one may have both peritoneal and retroperitoneal reaction from such a wound,

Postoperative. Postoperatively these patients should be given the consideration of any patient who has undergone gastrointestinal surgery. Usually the patient is kept in a semi-Fowler position. The stomach is constantly decompressed by continuous gastric suction. Water and electrolyte balance is maintained by parenteral administration. Chemotherapy should be continued, using penicillin, streptomycin and perhaps sulfadiazine in the dosage mentioned. Chemotherapy should be used for ten days postoperatively unless complications from infection demand continuation of the drugs. Sensitivity tests of the cultured organisms will indicate the specific chemotherapeutic agent to be used.

It should be apparent that with proper preoperative management, adequate correction of the rupture of the duodenum by operation and sustained management in the postoperative phase, these patients should survive such an injury. There is some reason to doubt that the mortality rate of 75 to 90 per cent should continue in these patients. Four cases of traumatic non-penetrating rupture of the duodenum due to violence are being reported, wit h recovery of all four patients.

CASE REPORTS

CASE 1. H. B. (C. G. H. No. 171946), a thirteen year old white male, was admitted to the Cincinnati General Hospital at 9:00 P.M., April 24, 1942. The history revealed that at 3:30 P.M. April 23, 1942, about twenty-nine hours before admission to the hospital, he had fallen about 7 feet from a tree house, landing on his back. He complained of generalized abdominal pain and about two hours after the accident became nauseated and did not eat. His pain became more manifest in the right lower quadrant of his abdomen and he did not sleep well during the night. The next day the pain, which was colicky in nature but also steady most of the time, gradually became worse; and after he had vomited several times and experienced anorexia, his mother brought him to the hospital.

On physical examination his temperature was 100.4°F., the pulse was rapid and weak with a rate of 160, respirations were 36 and the blood pressure was 90 systolic. Correct diastolic pressure could not be obtained. He was extremely ill with evidence of peripheral circulatory collapse. The examination

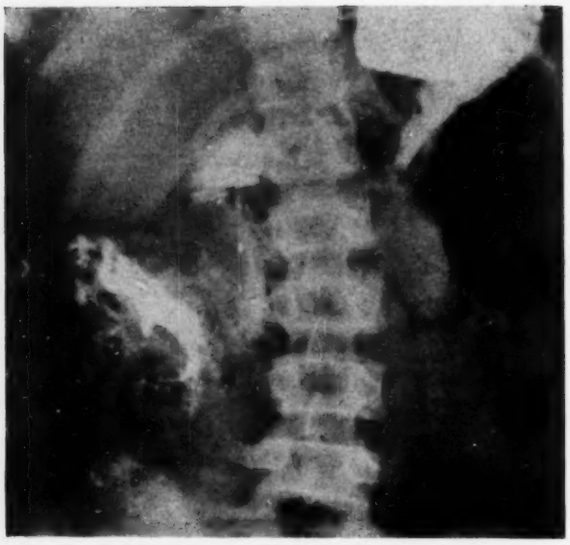

FIG. 1. Roentgenogram demonstrating the retroperitoneal fistula due to extraperitoneal rupture of the second and third portions of the duodenum.

FIG. 2. Drawing representing extraperitoneal rupture of the second and third portions of the duodenum.

was negative except for the abdomen in which there was slight distention with rather marked spasm of all of the abdominal musculature, most marked on the right side. Tenderness was more severe in the right lower quadrant. Rebound tenderness was present throughout but was most marked in the right lower quadrant. An occasional peristaltic movement could be heard in the extreme left abdomen but none was elicited elsewhere. No masses could be palpated. Rectal examination was non-contributory.

The white blood count on admission to the hospital was 32,400 and, except for an occasional cast, urinalysis was negative.

The clinical diagnosis was possible acute appendicitis and the possibility of rupture of a portion of the gastrointestinal tract was also considered. Because of the localization of the intra-abdominal disorder to the right lower quadrant, acute appendicitis was considered most likely even with the history of this trauma and operation was performed eight hours after admission to the hospital. A McBurney incision was made and the peritoneal cavity in the right lower quadrant was explored without revealing any evidence of acute appendicitis. A retroperitoneal exploration was performed by incising the posterior parietal peritoneum. This permitted the escape of a large amount of rather clear, watery fluid which had no odor. It was then believed that there was a retroperitoneal disorder, the etiology of which was undetermined at the time. The retroperitoneal space was drained with five cigarette drains brought out through the McBurney incision. Preoperatively as well as operatively this patient was treated for his peripheral circulatory collapse. Preliminary roentgenograms of the abdomen including a flat and upright film did not reveal any positive findings.

The patient tolerated this procedure fairly well; however, it was noted that his course was quite stormy. His temperature ranged between 99 and 104°F. during the first week. Supportive measures included the administration of whole blood, continuous gastric aspiration, intravenous administration of sodium sulfadiazine, the continued use of intravenous vitamin therapy and good nursing care. Finally his condition did improve and in an attempt to evaluate his condition further an upper gastrointestinal series was done. This revealed a duodenal fistula into the retroperitoneal space dissecting through this region to the right lower quadrant. (Fig. 1.) These films were taken on the patient's sixth and seventh hospital days, respectively. The roentgenologic examination was done because the McBurney incision continued to drain thin, watery material which caused considerable digestion of the epithelial structure of the abdominal wall and looked not unlike that of a pancreatic fistula. Further study of this material revealed that it contained pancreatic juice. This was the first suggestion that the duodenum might have been ruptured. Roentgenographic studies clearly defined the diagnosis. On the patient's tenth hospital day (eleven days after the initial fall) this patient submitted to exploratory laparotomy through an upper transverse abdominal incision. The duodenal region was immediately explored; and after the duodenum was mobilized by incision of the right lateral peritoneum, the second and third portions of the organ were easily mobilized. The duodenum was rotated toward the left gutter and a rent which almost encircled the duodenum half of its distance was seen at the junction of the second and third portions of its structure. (Fig. 2.) The wall of the duodenum was edematous and the

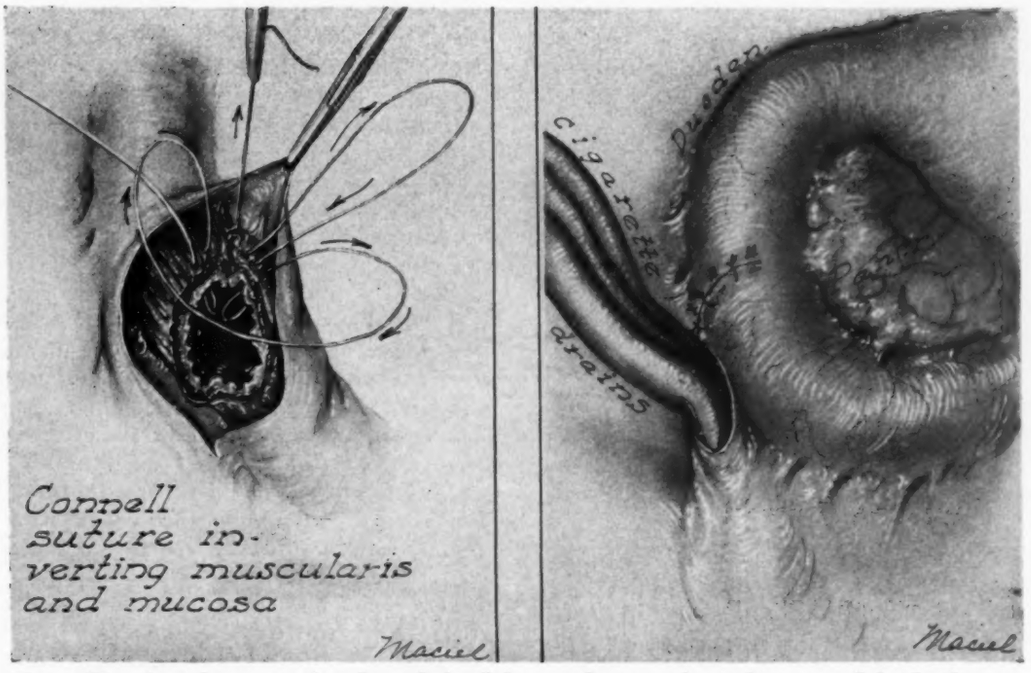

FIG. 3. Drawings demonstrating the technic of closure of extraperitoneal rupture of the duodenum.

edges of the rupture were somewhat irregular and devitalized. The mucous membrane was seen to protrude very distinctly through this tear. The mucosa was closed with a continuous No. 00 intestinal chromic catgut suture using the Cushing right angle stitch. The muscular coat was then used to reinforce the mucosal suture by means of the Halsted mattress suture with medium silk. Between each of these mattress sutures an interrupted suture of fine silk was placed. This adequately repaired the duodenum at the point of rupture. (Fig. 3.) Five cigarette drains were then placed in the retroperitoneal space and these drains were brought out through the right lateral angle of the working incision. The incision was then closed with through and through silver wire stay sutures. Five Gm. of sulfanilamide were placed in the peritoneum. No attempt was made to close the peritoneum and fascial structures of the anterior abdominal wall.

He was given all of the supportive measures which follow such an operative procedure, namely, gastric aspiration, sodium sulfadiazine, maintenance of water and electrolyte balance by parenteral fluids, the adequate utilization of whole blood intravenously and adequate doses of vitamins daily. His response postoperatively was excellent, his temperature ranging between 99 and 102°F. for four to five days after which it gradually returned to a normal level. On the sixteenth postoperative day his temperature was normal; he was discharged from the hospital as well on the forty-first hospital day.

Comments. This is an example of an extraperitoneal rupture of the duodenum due to violence. This case represents an example of misinterpretation of an extraperitoneal rupture of the duodenum with retroperitoneal extension of duodenal secretion to the right lower quadrant. The initial clinical diagnosis was acute appendicitis.

CASE II. L. B. (C. G. H. No. 157711), a white male age twelve, was brought to the Cincinnati General Hospital on June 2, 1945, two hours after he had received injuries to the abdomen and left forearm. This child had been crushed between a truck and a boxcar. His complaints at the time of admission concentrated about the abdomen where there was tenderness in the epigastric region. He complained also of pain in his left wrist.

Physical examination was essentially negative except for the abdominal findings. Temperature was 100°F., pulse 88, respirations 28 and the blood pressure was 130 systolic over 90 diastolic. Examination of the abdomen revealed right rectus muscle spasm chiefly located in the right upper quadrant with questionable rebound tenderness. There was evidence of shifting dullness, revealing clinically the presence of fluid in the peritoneal cavity. Peristalsis was absent. On rectal examination there was mild tenderness on both sides. There was a Colles' fracture of the left wrist.

The clinical diagnosis was Colles' fracture of the left wrist, possible contusion of the liver and possible rupture of a hollow viscus. The patient was

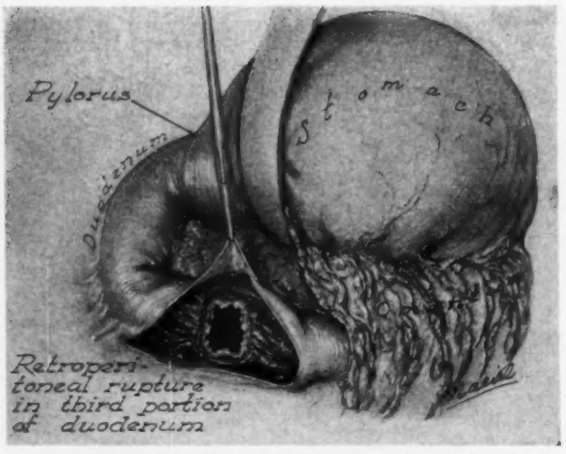

FIG. 4. Drawing representing extraperitoneal rupture in the third portion of the duodenum.

placed on surgical observation after treatment of the Colles' fracture. In the interim of a few hours he vomited three times. The vomitus consisted of gastric material which did not reveal the presence of blood. He definitely became more apprehensive and within four hours the pain in the right upper quadrant and the epigastric regions increased. There was evidence of right rectus rigidity with rebound tenderness referred to the right side. A left decubitus roentgenogram revealed no air in the peritoneal cavity. At this time the white blood count, which on admission was 11,300, had risen to 28,350. Within eight hours after the accident the temperature rose to 101.6°F., the pulse increased to 120 and the respirations were 28. There were definite signs of increasing peritoneal irritation and the patient became markedly drowsy. The entire right abdomen was rigid and exquisitely tender. At this time the definite diagnosis of a ruptured hollow viscus, probably in the duodenum, was made. The patient was prepared for operation by the administration of 1,000 cc. of 5 per cent glucose and saline; ten hours after the injury he submitted to exploratory laparotomy.

Operation was done through an upper transverse incision. Beneath the right portion of the gastrocolic omentum there were collections of fluid of a greenish yellow color strongly resembling the appearance of bile. The fluid had dissected down to the right lumbar gutter in the retroperitoneal space and also upward toward the foramen of Winslow. The greatest concentration of the fluid was at the base of the mesocolon in front of the right kidney at the junction of the second and third portions of the duodenum. The retroperitoneal space was entered by incising the peritoneum to the right of the second portion of the duodenum. The bile-stained fluid was aspirated and by sharp and blunt dissection the second portion of the duodenum was exposed. A laceration was found which extended approximately halfway around the duodenum in a transverse direction just at the junction of the second and third portions. (Fig. 4.) Bile poured freely from the laceration. The second and third portions of the duodenum were mobilized so that both sides of the area of laceration were adequately exposed. Traction sutures of silk were placed at either end of the laceration and the mucosa was closed with a running lock stitch of No. 000 chromic intestinal catgut. This suture line was reinforced with Halsted mattress sutures of medium silk and interrupted sutures of fine silk were placed between each Halsted mattress suture. Two cigarette drains were placed in the retroperitoneal space and one Penrose drain in the right paravertebral gutter. The abdominal wound was then closed with through and through wire sutures. The drains were brought out through a stab wound just below the twelfth rib. The posterior rectus sheaths and peritoneum were closed with No. 0 chromic catgut and the anterior rectus sheaths were closed with interrupted No. 0 chromic catgut sutures. The edges of the skin were approximated with interrupted sutures of fine silk. A Levin tube was placed in the stomach while the patient was still under anesthesia and he was returned to the ward in good condition.

The postoperative course was essentially uneventful. The patient was given nothing by mouth for a period of seventy-two hours after which time he was started on a Cornell diet. He was given parenteral fluids and chemotherapy in the form of penicillin and sulfadiazine. His temperature postoperatively ranged around 102.6°F., the pulse between 100 and 120 and the respirations between 30 and 44. All of these clinical observations gradually fell so that by the eighth postoperative day they could be considered within normal limits. On the tenth postoperative day the patient began to have an intermittent fever. This type of febrile response was not explained except on the basis of possible reaction to the chemotherapeutic agents. The possibility of subphrenic abscess was also considered. X-ray and fluoroscopy of the diaphragms and thorax did not real the presence of a subphrenic abscess. Repeated examination of the chest and diaphragms revealed no pathologic condition and at this time the white blood count was within normal limits. By the thirteenth postoperative day the temperature, pulse and respirations were within normal range and remained so until the patient's twenty-fourth hospital day at which time he was discharged. Sulfadiazine was discontinued on the tenth postoperative day and penicillin was discontinued on the seventeenth postoperative day.

This patient was watched in the surgical follow-up clinic. He has been seen eleven times since this accident occurred, the last visit having been February 15, 1948. At no time have there been any complaints referable to the gastrointestinal

tract and his postoperative course has been considered excellent in all respects. There was no evidence of hernia in the transverse abdominal incision.

Comments. This is an excellent example of a non-penetrating extraperitoneal rupture of the duodenum due to violence diagnosed eight hours after the injury and operated upon ten hours after the injury.

CASE III. A. P. (C. G. H. No. 213967), a forty-nine year old white male, entered the Cincinnati General Hospital on the orthopedic service because of a tumor mass in the region of the right ilium. He entered the hospital May 20, 1946, after having been seen in the gastric clinic the same day. The history revealed that he had fallen on a rock five months before admission to the hospital and had injured his right side, particularly the right pelvis. Immediately after this accident he remained in bed for about two days with pain in the abdomen and over the right pelvic region. This pain continued for a period of about four days and then tended to subside although the patient stated that he did not feel well during this inteval. Three months before admission he began to have sharp, knife-like gas pains in the lower abdominal region; these were continuous both day and night with disturbance of bowel habits in the nature of obstipation and constipation. At this time the patient had a weight loss of 28 pounds in three months. The remainder of his history was essentially negative.

Physical examination revealed his temperature to be 98°F. on admission with pulse 68 and respirations 20. The white blood count in the admitting ward was 19,000. Examination was for the most part negative except in the abdomen. Here over the right iliac crest a large, circular, intra-abdominal mass measuring approximately 8 by 10 cm. could be palpated. This was exquisitely tender and very painful to palpation. There was a suggestion of fluctuation of this mass although the observers could not agree on this finding. Most observers agreed that the mass lay in the retroperitoneal tissues. The remainder of the abdominal examination was essentially negative.

The working clinical diagnosis covered many possibilities including osteomyelitis of the ilium, retrocecal abscess, perinephritic abscess, ruptured duodenal ulcer with subphrenic abscess, malignancy of the ascending colon and malignancy of the right kidney. Among many clinical determinations a barium enema was done which revealed a definite constricting angular lesion of the mid-ascending colon. These findings were compatible with a primary malignancy of the ascending colon. However, the roentgenologist believed that the soft tissue mass might represent a second pathologic lesion and, therefore, an abscess from a perforated carcinoma of the colon was considered as a likely possibility. The patient's general condition was good. During the course of observation the temperature, pulse and respirations rose gradually so that by the third hospital day his temperature ranged around 102°F. at which time his white count varied between 10,000 and 17,000. The pulse was also elevated during this period and respirations ranged between 20 to 24. On the fourth hospital day the patient was placed on penicillin therapy which was continued for a long period of time. The roentgenologic findings also suggested possible involvement of the wing of the right ilium and for this reason the patient was admitted to the orthopedic service. Although he was presented to the orthopedic staff, it was believed that a good possible diagnosis was that of a retroperitoneal tumor or abscess. It was suggested that medical and surgical consultation be obtained. The medical consultants believed a likely diagnosis to be osteomyelitis with abscess formation of the right ilium. Both acute and chronic osteomyelitis were considered as a possibility. It was the opinion of the surgeons that this patient could have one of many possibilities; however, both inflammation in the nature of a retroperitoneal abscess and the possibility of a primary carcinoma of the ascending colon with perforation were considered to be the most likely possibilities. It was the suggestion of the surgical department that this patient have a drainage of his abscess and that a biopsy of pertinent tissue be taken at that time.

On June 7, 1946, the patient's eighteenth hospital day, incision and drainage of the abscess was done. At this time the patient was placed on chemotherapy consisting of both penicillin and sulfadiazine. Very promptly there was response and his temperature, pulse and respirations returned to a normal limit. Biopsy was done at this time but was non-specific as far as diagnosis was concerned. The patient then had a repeat examination of his barium enema at which time the roentgenologist considered carcinoma of the ascending colon as a likely diagnosis. (Fig. 5.) The diagnosis of an infected granuloma was all that could be considered from the biopsy. Because of the findings in the mid-ascending colon it was believed that definitive therapy should be established. Therefore, on June 22, 1946, the patient's thirty-third hospital day, he was operated upon with a tentative diagnosis of carcinoma of the ascending colon with perforation and abscess formation of the right flank. The abdominal cavity was explored through a transverse incision which was started about 2 cm. above the right anterior iliac spine and extending to just beyond the midline about 3 cm. below the umbilicus. There was no free fluid in the peritoneal cavity. The liver, gallbladder and stomach appeared to be normal. The

FIG. 5. Roentgenogram (barium enema) showing annular constriction of the mid-portion of the ascending colon; this constriction was proven to be due to adhesions from a previously extraperitoneally ruptured duodenum.

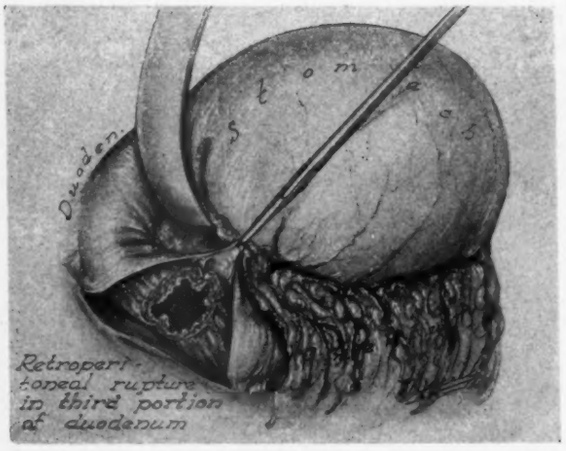

FIG. 6. Drawing representing extraperitoneal rupture of the third portion of the duodenum.

mid-portion of the ascending colon was densely bound down by adhesions. These adhesions apparently were so placed in the mid-ascending colon as to produce an annular constricting appearance in the roentgenograms studied by barium enema. The cecum was free and the appendix and ileum appeared normal. There was no mass in the region of the ascending colon. The origin of the abscess in the right flask was apparently from a retroperitoneal point. It was decided to explore the hepatic flexure of the colon and the adhesions in this region were incised in order to mobilize the bowel. As the hepatic flexure was finally freed, the second and third portions of the duodenum were exposed. There were numerous extremely dense fibrous adhesions between the hepatic flexure of the colon and the junction of the second and third portions of the duodenum. Final exploration of this region revealed an old laceration of the duodenum in its second and third portion which had been sealed off by granulation tissue for a long period of time. There was no evidence of a duodenal ulcer in this location and certainly no evidence of tumor. By mobilizing the peritoneum to the right side of the second and third portions of the duodenum and rolling this part of the duodenum anteriorly and to the left laterally, the retroperitoneal tear was found. This tear was about 3 cm. in length and was in an oblique position. (Fig. 6.) The mucosa of the tear was closed with a No. 000 chromic intestinal catgut suture of the Cushing right angle type. The serosa and muscular coats were reinforced with Halsted mattress sutures of medium silk and between each of these an interrupted suture of fine silk was used for reinforcement. There was considerable scar tissue and adhesions about the lower pole of the right kidney and there was evidence of a sinus tract which led posteriorly and retroperitoneally inferior to the pole of the kidney and anterior to the iliopsoas muscle. This sinus tract communicated with the old abscess which had previously been drained. Four cigarette drains were placed in this retroperitoneal region and brought out through a separate stab wound in the right flank. The abdominal working incision was then closed with through and through steel wire stay sutures and the peritoneum and posterior rectus sheath closed with a continuous No. 0 chromic catgut suture. The anterior rectus sheaths were not closed. The edges of the skin were approximated with interrupted sutures of fine cotton.

The postoperative course from this point was excellent and there was little or no febrile response to the operative procedure, the temperature having risen to 101°F. for one twenty-four-hour period after which it remained essentially normal. He was given supportive therapy in the form of whole blood and blood plasma and chemotherapy was continued in the form of sulfadiazine and penicillin. The wound healed without infection and the patient was discharged from the hospital on his twelfth postoperative day and his fifty-third hospital day.

This patient has been seen five times in the surgical follow-up clinic and it is the opinion of all clinicians that he has made an uneventful recovery. He was last seen September 15, 1946, at which time he had no complaints referable to his gastro-

intestinal tract. The abdominal wound was well healed and there was no evidence of hernia.

Comments. This is an excellent example of traumatic rupture of the duodenum of the retroperitoneal variety. The process of infection was walled off so that an acute to chronic retroperitoneal abscess developed which pointed in the right lower quadrant as a large indefinite mass. In this process a sinus tract developed between the second and third portions of the duodenum to the right lower quadrant. The infection remained localized over a long period of time so that there were definite changes in the appearance of the wing of the right ilium and, therefore, the diagnosis of involvement of bone was made. Because of the chronicity of this affair and because the adhesions constricted the wall of the ascending colon externally, the diagnosis of carcinoma of the ascending colon with perforation of the carcinoma and abscess formation was considered the most likely preoperative diagnosis. At operation the rupture of the duodenum was closed and the patient made an uneventful recovery.

FIG. 7. Roentgenogram demonstrating intraperitoneal sinus due to rupture of the third portion of the duodenum.

CASE IV. R. M. (C. G. H. No. 246425), a thirty year old white male, was admitted to the Cincinnati General Hospital almost immediately after having had a head-on collision in his automobile. He was admitted on January 1, 1949, approximately one hour after the injury. His history revealed that when he had the head-on collision, he attempted to cover his face with both hands; and in so doing he turned toward the left so that his right upper abdomen was forcibly thrust against the steering wheel of his automobile. He had been drinking and there was some element of confusion about the incidents that followed immediately after this injury.

On clinical examination his temperature was found to be 97.6°F., pulse 84 and respirations 20. The blood pressure was 104 systolic over 60 diastolic; the white blood count was 26,800. The general physical examination was essentially negative except for the abdominal findings of severe tenderness in the right upper quadrant with marked tenderness over the right thoracic cage anteriorly and laterally. There was marked muscle spasm of the upper abdominal muscles and rigidity over the right upper quadrant. Peristalsis was absent. There was rectal tenderness diffusely but no evidence of localization. Roentgenograms consisting of a flat and an upright film of the abdomen were negative for the presence of pneumoperitoneum. Possible laceration of the liver, possible fractured ribs and the possibility of acute traumatic pancreatitis and of a ruptured hollow viscus were considered as likely diagnoses. This patient was admitted to the surgical service and observed over a period of several hours. Within eight hours after admission the patient vomited on two occasions and the serum amylase was found to be elevated to 564 units with a white count ranging around 25,000. The patient was placed on continuous gastric suction and given nothing by mouth. He was also given chemotherapy in the form of penicillin and streptomycin. Because of the elevated blood serum amylase the diagnosis was limited to two possibilities, acute traumatic pancreatitis and the possibility of a ruptured duodenum. As a matter of fact, most of the clinicians who saw this patient considered both of these possibilities. The patient maintained a relatively normal plateau and in the course of forty-eight hours appeared to be somewhat improved although his temperature was still elevated between 100 and 101°F. and the serum amylase was maintained about 600 units. By the end of seventy-two hours the white count began to rise. Because of the absence of peristalsis and because of the septic course and the elevated white blood count roentgenograms of the abdomen, including fluoroscopy of both diaphragms, was done on the patient's

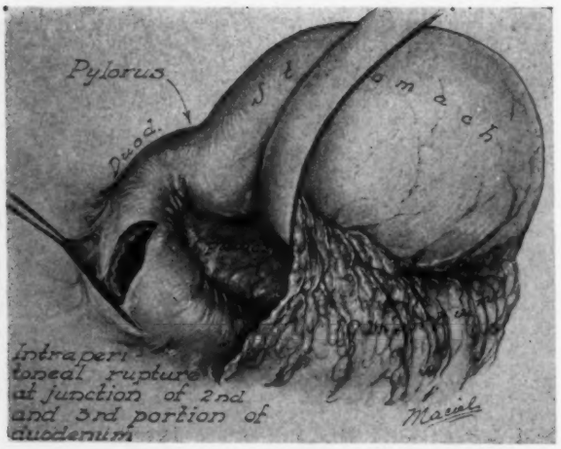

FIG. 8. Drawing representing intraperitoneal rupture of the second and third portions of the duodenum.

fourth hospital day. Also at this time 15 cc. of iodized oil were introduced through the Levin tube in the patient's duodenum. This iodized oil was seen to pass through the duodenum and, as it entered the second and third portions of the duodenum, it passed into a sinus tract which lay over the anterior aspect of the right iliopsoas muscle paralleling the angle of the duodenum. This oil extended from the duodenum for a distance of approximately 6 cm. On the basis of this roentgen study (Fig. 7) a diagnosis of traumatic perforation of the descending arm of the duodenum with a large-sized sinus tract proceeding caudally in the retroperitoneal space was made. This patient was observed because of the definite proven diagnosis of acute traumatic pancreatitis. It was the belief of the clinicians that although the patient did have a rupture of the duodenum, his general condition was excellent; and, therefore, early exploration in the presence of the traumatic pancreatitis would not have been considered as good judgment as careful observation.

On the patient's tenth hospital day exploratory laparotomy was done through an upper transverse incision at which time a transverse tear at the junction of the second and third portions of the duodenum in the intraperitoneal portion was found. (Fig. 8.) There were considerable adhesions about this portion of the gastrointestinal tract between the omentum, transverse colon and the duodenum. The omentum and transverse colon were freed by cutting these adhesions and a rent which was approximately 3 cm. in length and ran obliquely across the second and third portions of the duodenum was encountered. The edges of the duodenal wall were hemorrhagic and edematous. The mucosa was approximated with a continuous No. 00 chromic intestinal Connell suture. (Fig. 9A.) The muscular and serosal coats of the duodenum were reinforced with Halsted mattress sutures of medium silk and interrupted sutures of fine silk were placed between each of these mattress sutures. (Fig. 9B.) This gave adequate closure of this perforation of the duodenum. Two Penrose drains were placed to this portion of the duodenum and were brought out through a separate stab wound in the right flank. The upper transverse incision was then closed with through and through steel wire sutures, the peritoneum and posterior rectus sheaths having been approximated with No. 00 chromic catgut sutures. The anterior rectus sheaths were also approximated with interrupted No. 00 chromic catgut sutures and the edges of the skin were approximated with fine silk sutures.

The patient responded well to this operative procedure. All general supportive measures were used including whole blood and blood plasma. Chemotherapy in the form of penicillin and sulfadiazine was given and on the patient's fourth postoperative day his temperature, pulse and respirations fell within a normal limit. Chemotherapy was continued until the patient's seventh post-

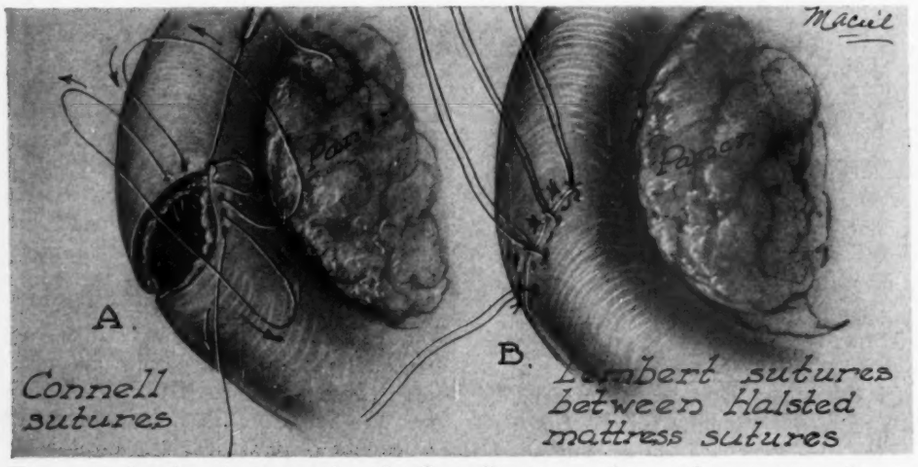

FIG. 9. A, drawing demonstrating the Connell suture to invert the mucosa and muscularis layers of the duodenum; B, drawing demonstrating reinforcement of the mucosomuscularis suture using Halsted mattress sutures and interrupted sutures.

operative day at which time they were discontinued. The patient had no complications whatever and was discharged on his twenty-fifth hospital day.

Comments. This is an example of an intraperitoneal acute rupture of the duodenum due to violence associated with acute traumatic pancreatitis. It is questionable whether the patient should have been explored earlier in the course of this illness although his response to this operative procedure as late as the tenth post-traumatic day was excellent. Had he been operated upon earlier within the first twenty-fourth to forty-eight hours, one might question whether or not further damage would have been done to the pancreas with a resultant stormy postoperative course.

SUMMARY

A series of four acute ruptures of the duodenum due to violence has been reported. One of these cases (Case IV) represents intraperitoneal rupture of the duodenum while Cases I, II and III represent retro- or extraperitoneal rupture of the duodenum. Interestingly enough these are the only four cases which we have seen in the Cincinnati General Hospital between the years 1942 and 1949 inclusive. The mortality rate from this type of trauma has been reported to be between 75 and 90 per cent. There was no mortality in the four cases presented. It is to be noted that all four of these cases are different in all respects. In Case I the diagnosis of acute appendicitis with abscess formation, which proved to be erroneous, was made. In Case II the diagnosis was made early in the post-traumatic period and the patient was operated upon within ten hours. In Case III the acute rupture of the duodenum apparently was walled off readily. Therefore, a long-standing retroperitoneal abscess developed which pointed in the patient's lower right quadrant and in so doing created adhesions about the mid-portion of the ascending colon. These complications permitted the erroneous clinical diagnosis of carcinoma of the colon with perforation and abscess formation. This patient was operated upon approximately five months after the perforation had occurred. In Case IV the diagnosis of rupture of the duodenum was considered early in the post-traumatic period. However, the positive diagnosis of traumatic pancreatitis was made by the laboratory determination of an elevated blood serum amylase. In this instance the patient's condition improved and, therefore, exploration was delayed because of the likelihood of disturbing the pancreatic condition. The patient was operated upon on his tenth post-traumatic day and made an uneventful recovery. Unquestionably chemotherapy has done a great deal to improve the survival rate.

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DISCUSSION OF ARTICLES BY DRS. DEVINE AND BURWELL, SANDERS, MAGUIRE AND MOORE, WECKESSER, CHINN AND SCOTT, AND SILER

J. Maxwell Chamberlain (New York, N.Y.): It is a pleasure to be able to discuss these very interesting papers before this Society. As a thoracic surgeon I should like to limit my discussion to the thoracico-abdominal incision as pointed out in the paper by Dr. Devine and Dr. Moore.

There are two points of interest to me. These have to do with anesthesia and the care of the open chest postoperatively. As Dr. Devine pointed out, he did not have an intratracheal tube in place; and I should like to emphasize that the intratracheal tube, although desirable, is not essential. As you all know, when the chest is opened, the tidal exchange of air is immediately reduced; but with a tight-fitting mask and intermittent or rhythmical compression of the anesthetic bag this reduction in tidal excursion can be compensated for by the anesthetist. If the tidal air under pressure which enters the pharynx goes via the esophagus into the stomach, the abdomen is already open; and the surgeon is immediately aware of this. Usually, however, the sphincteric tone of the cardia is such that the stomach does not inflate during the compression by the anesthetist.

Now, in the postoperative care of the open chest perhaps the safest thing to do is to drain or put a catheter into the pleural space postoperatively and drop this tubing down beneath water. It is not essential. One may put in penicillin or some other drug to combat a possible infection but there is really no reason to substitute chemotherapy for good surgical principles. As we all know, obliteration of dead space is one of the first principles of surgery. If complete re-expansion of the lung is achieved by drainage of the pleural space using a water seal to prevent the air from getting back into the thorax, infection is not likely to occur. In twenty-four to forty-eight hours this tube is removed.

It is a pleasure to see the modern, well trained general surgeons enter the thorax with no fear. If proper anesthesia is used and proper care of the chest is observed postoperatively, there should be no hesitancy on the part of the surgeon to open the chest and achieve the necessary exposure which is essential to good surgery.

R. Arnold Griswold (Louisville, Ky.): The only thing I would like to point out with reference to these wounds of the liver is the advisability of débriding the liver just as you would débride any other tissue. Surgeons traditionally are afraid of the liver because of the danger of hemorrhage. As you saw in Dr. Moore's second case, the liver was

not débrided. That man had secondary hemorrhage and almost died. In the first case, in which the patient got along very well, the autolyzed liver tissue was débrided.

Dead liver tissue not only is a great cause of secondary hemorrhage but also is extremely toxic if left in the abdomen. Therefore, I should like to enter a plea for adequate surgical débridement of the liver just as you débride any other contused, dead or damaged tissue.

JOHN L. ATLEE, JR. (Lancaster, Pa.): I am very glad to have the opportunity to discuss these cases, particularly the liver injuries.

I think the most important thing in all of these cases is to know when to operate. Too often one sees deferment of decision as to when to do it. Our experience has been rather limited. We had one case that was packed with oxidized cellulose in which the liver was not débrided and which was troubled with secondary hemorrhage. We had another case that was not so massive in which the liver was débrided and in which gelfoam was used. I have no thought about either particular hemostatic substance. It seems to me they are both good. The second case did not have any hemorrhage.

I should like to impress one factor, that is, to be prepared to make a thoracico-abdominal approach.

One other patient, a child, had a laceration of the spleen associated with injury to the left lobe of the liver and to the stomach from a falling anvil on a farm. I am sure that case could never have been handled in any other way than by thoracico-abdominal approach.

EVERETT P. COLEMAN (Canton, Ill.): I should like to discuss the paper on massive resection of the intestine and report two cases with which I have had some interesting experiences. The term, massive resection, has been coined to apply to intestinal resections with the arbitrary limit of 5 feet; that is, anything over 5 feet is listed as a massive intestinal resection.

The first case was that of a middle-aged woman who was seen about twelve years ago with a recurring jejunal intussusception which had been compounded four times. At the time of operation the inner layers of this intussusception were found to be gangrenous and a resection of 5 feet 6 inches of bowel was found necessary. In this case all the jejunum was removed and a portion of the upper ileum. In spite of the loss of secretions from the jejunum, which are supposed to stimulate further intestinal secretions for the aid of digestion, she has had no unusual symptoms. Her postoperative course has been entirely uneventful and there are no digestive symptoms of any type. She can eat anything and has no anemia or diarrhea. She has had a moderate gain in weight and when last seen was restricting her diet somewhat to avoid the "middle-aged spread."

The second case gave an entirely different postoperative picture. The patient was a young man who received a shotgun wound of the abdomen with extensive destruction of the right half of the colon and practically all of the ileum. At operation it was found necessary to remove 15 feet 8 inches of intestine. In this case all of the ileum and the right half of the colon were removed. After a very stormy recovery period he seemed to be in fairly good condition but I have had the opportunity for the last eight years to observe him at intervals. Most of the time he has been quite troubled with diarrhea, particularly when he ate food with a large amount of fat in it. He has been rather emaciated although he was of this type of build prior to his injury. He seemed to do best on a high carbohydrate diet with quite a little protein but being a fisherman, on occasion temptation was too great to be resisted and he would go on a "bat" of fried catfish and corn on the cob. As a result he comes to the hospital from time to time with a very intractable diarrhea. We put him on a high carbohydrate and protein diet and he will get along quite nicely; the diarrhea will clear up and he will handle food with apparent efficiency of his digestive apparatus so long as he avoids fats. During this period he has taken very poor care of himself from the medical standpoint and, as a result, returns about once a year with a rather profound hyperchromic anemia. According to the blood findings and to sternal puncture it is not a pernicious anemia but simply an iron deficiency anemia and about once a year he has to have about 2,000 cc. of blood. He comes in pretty well down in his red count and hemoglobin with no microscopic blood evidences of pernicious anemia. We will give him four transfusions and then he will gain and go home doing fairly well from the anemia standpoint until the next year. He has learned, little by little, to avoid fried catfish and corn on the cob with occasional exceptions. In our opinion the inability of the jejunum and distal colon to absorb iron from his diet is the major factor in producing the anemia. However, in the past year an interesting change has occurred. In his last hospital stay, nearly a year ago, he was given liver extract hypodermically in addition to his transfusions to help overcome his anemia. A nurse who is employed part time in the hospital lives near him and gives him liver extract hypodermically at weekly intervals. Following this, over a period of several months he has remained free from anemia, has gained in weight and is in a better state of nutrition than at any time in his life. Apparently, with the sole addition of liver extract, with the diarrhea controlling factor of a high carbohydrate and protein diet and with the avoidance of fats, he will now be able to live a fairly normal existence with a minimum of discomfort.

LOUIS G. HERRMANN (Cincinnati, O.): I should like to emphasize some of the things that Dr. Siler has already told you.

We are convinced that these injuries to the duodenum, particularly in the retroperitoneal portion, are much more common than is ordinarily supposed. We believe we should keep in mind this injury to the duodenum in all forms of trauma to the upper abdomen.

Dr. Siler's cases showed that even in well-organized surgical clinics there is considerable delay sometimes in recognizing the injury to the duodenum or in carrying out definitive treatment. It is for the purpose of bringing this syndrome to your attention that Dr. Siler has presented these cases. If we can recognize these lesions early, the mortality rate from this type of injury can be reduced greatly.

H. Gurth Pretty (Montreal, Canada): I think I have been put on the spot a little here by having the Chairman invite me to discuss these papers but I have been suspecting it for some time.

These papers are particularly interesting because I can recall numerous occasions when these things have happened. In the first place, with all due respect to our present knowledge and treatment, laboratory findings, when I recall some of the old writings of De Quervain, with special reference to rupture of the small gut, I still think that these articles are well worth going back over and rereading.

My experience with rupture of the duodenojejunal juncture has been in connection with the pulp and paper industry when they first started using tractors. These tractors went plowing through the mud and suddenly a stick of pulpwood got caught under the tractor. Then men who were following behind were just fired at as though they were hit by a machine gun. On one occasion three men were "picked off" with a stick of pulpwood.

Another point is that on many occasions I have run into rupture of the liver with children playing, throwing balls, etc. I can recall one instance in which a youngster was chasing a tennis ball. The tennis ball bounced back in front of a hydrant. Three other boys piled in behind the boy and drove him up against the hydrant; he got a ruptured liver through the cleft.

Now, I wish that I had known about the thoracico-abdominal approach in those days. I would not have had as much trouble as I had at that time in closing the liver. We did not have gelfoam, vitamins C, K or anything else at that time. All we did was take a piece of the rectus muscle, put it on either side of the liver cleft and then put microsutures through.

I was interested in the point regarding laceration of the liver, that most people were draining it. My experience has been that we were not draining our abdominal cavities. Whether that is introducing more trouble, I do not know. However, I was interested in the fact that these were drained, but in spite of that you were running into subphrenic abscess. I would like to hear some remarks on that point.

These papers were most interesting, and I think it is a very good series to bring before this Society.

Charles G. Johnston (Detroit, Mich.): In the Detroit Receiving Hospital we see rupture of the duodenum occasionally. In the case which Dr. Siler presented last it seemed to me that the patient must have been an exceedingly sturdy man because these patients are very sick. A man who has had a rupture of the duodenum with free blood and obviously duodenal material from a hole as large as he had, must have been a pretty sick individual. The question I wanted to ask him is: How often has he seen the diagnostic feature of fine bubbles of air in the retroperitoneal space, either going down along the psoas, or the thing we have seen (which I have not seen in the literature), fine bubbles of air in under the liver, finely dispersed, on the flat film of the abdomen.

On two occasions we have diagnosed definitively a rupture of the duodenum on the basis of the flat film with small bubbles of air and I think that should always be looked for in any patient. We believe that the flat film of the abdomen is an important adjunct to diagnosis and so far as ruptured duodenum into the retroperitoneal area, it is an exceedingly important and definitive diagnostic picture. If you see it, you can be sure of it. So often we do not see it and I wanted to know from Dr. Siler whether he had observed this in his cases and how many times.

Vinton E. Siler (Cincinnati, O.): I would like to make a comment about Dr. Weckesser's paper.

He brought up the question of how much small bowel can be removed and still have a patient survive. I would like to report that a patient, twenty-seven years of age, entered our hospital a year and a half ago at which time a diagnosis of internal hernia was made. After resection this patient had 18 inches of jejunum left so that a jejunocolostomy was done. This patient was followed up very carefully not only by the surgical department but also by the medical service and has subsequently been observed by Dr. Richard Vilter who has directed complete studies.

When last seen eighteen months postoperatively, he was on a regular diet and had not developed any type of anemia. I think this might be at least an answer to Dr. Weckesser's question. We all realize that this patient might live many months and then, all of a sudden, develop an uncontrollable anemia resulting in death. Many problems in massive resection of small bowel have not yet been answered.

George B. Sanders (Louisville, Ky.): I would like to make one or two comments about Dr. Weckesser's paper in regard to the use of Tween-80.

I have at the present time three patients who have been maintained on Tween-80 for about six

months to a year. Two of these patients had right hemicolectomy with accompanying resection of about 3 to 4 feet of small bowel. They did not do particularly well from the nutritional standpoint after operation and were both placed on large doses of Tween-80 anywhere from two to four months after operation.

At that time I had no facilities available for the quantitative study of their stools so that my only evidence of improvement or the effect of Tween-80 was in their gain in weight and in the decrease in number of their stools from six in twenty-four hours to an average of two or three. Both patients manifested this definite change and improvement after being on the Tween-80 for about a week.

The third case is a little more interesting and more satisfactory because this man had an ileostomy for ulcerative colitis. He was maintained for about four months in a rather precarious nutritional balance but doing, we might say, satisfactorily, except that he did not gain weight but maintained a weight of about 75 to 80 pounds. At four months after his ileostomy, at which time I believe that any improvement in his nutritional status from the ileostomy alone would be ruled out, he was placed on Tween-80 and the change in the number of his stools or his ileostomy discharges in twenty-four hours was quite dramatic. They were reduced two-thirds or more after three days of being on Tween-80. He then immediately began to gain weight, adding approximately 35 pounds.

I would like to ask Dr. Siler one question with regard to extraperitoneal rupture of the duodenum. Occasionally there occurs in conjunction with this a very distressing thing, which is rupture of the retroperitoneal or retroduodenal common duct. It is a difficult thing to pick up and in my experience at least once has subsequently caused the death of the patient after we thought everything had been put in order.

I would like to ask, Dr. Siler whether it would not be advisable in each case of retroperitoneal rupture of the duodenum to visualize the papilla of Vater transduodenally and do a retrograde exploration of the retroperitoneal common duct to be sure that this has not occurred.

Frank H. Mayfield (Cincinnati, O.): If a neurosurgeon can get into this discussion, I would like to comment on Doctor Siler's case with pain in the low back and hip. I do not recall whether there was actually a disease of the hip but back and leg pain is not rare with disease of the posterior wall of the duodenum. I have seen a total of six patients whose presenting symptom was low back and hip pain which resembled injuries of the intervertebral disc which proved to be due to penetrating ulcers of the posterior wall of the duodenum. Two of these had been explored as intervertebral disc suspects. The fact that rupture of the duodenum is often precipitated by trauma makes it difficult to differentiate them from spinal lesions.

Howard E. Snyder (Winfield, Kan.): I should like to add to the discussion of the first two papers further remarks on the thoracico-abdominal approach on the right side.

I want to congratulate both of the men who have used it in the management of rupture of the liver. I should like to point out that it is occasionally useful in the gunshot wound and the thoracico-abdominal wound on the right side, and that surprisingly good exposure can be obtained in the right upper quadrant of the abdomen when the thoracic incision is carried only a few inches through the abdominal wall.

I recall one case in which the diaphragm and liver were perforated, the shell fragment lodging posterior to the duodenum. The thoracico-abdominal wound was taken care of, the fragment removed and the wound in the duodenum closed very satisfactorily through such an incision.

I think a point was brought out which is a very good one; that is, the location of the incision should depend upon the injury and that can often be very nicely determined in a penetrating wound where a shell fragment remains or in a perforating wound in which there are both wounds of entrance and wounds of exit.

The other point I should like to discuss is the matter of drainage. It was always my belief that a liver wound should be drained; and, a further point of importance, that when the liver wound was part of a thoracico-abdominal wound, the diaphragm should always be securely closed, preferably with non-absorbable sutures. Also, drainage should be carried beneath the diaphragm to avoid the development of a hepatopleural fistula.

John W. Devine, Jr. (closing): I would like to thank Doctors Chamberlain and Snyder for their remarks but I will have to differ with my friend, Doctor Chamberlain, on one point.

It was very kind of him to say that he was glad to see the general surgeon opening in the thoracico cage without fear but the profuse hemorrhage that I encountered already had me scared. And how scared can one get? As a matter of fact I have a confession to make on this case. I got into it by accident. The people had called my father but he was operating in another hospital so he sent me.

When I got in and placed the retractor beneath the upper end of the incision and saw what I was dealing with, I was reminded of an old story that I know some of you have heard about a southern surgeon who also had a son. The father had seen this fat colored woman with a large fibroid complicated with pelvic inflammatory disease and scheduled her for operation on a certain Tuesday afternoon. When the time arrived, the father was busy so he sent his son. The old girl did not like that very much but finally, with a great deal of

persuasion, she consented to the son operating. The operation was performed under spinal anesthesia. The situation was getting tense, as any of you know it can if you have ever done any pelvic surgery in the South. The patient, realizing the gravity of the situation, looked up and said, "O Lord, come down here on this earth and help me; and Lord come yourself and don't send your son, 'cause this ain't no place for children!"

ROY H. MOORE, JR. (closing): As to the question of débridement, in the first case that we presented the indication was quite clear. The liver was pulped and fragmented and it was obvious that débridement was necessary. In the second case, which presented a clean extensive cleft of the liver, in my own mind I am still not clear as to how débridement in this type of injury should be carried out, how much liver should be removed and how much of a problem hemostasis would be.

To answer the question on drainage, these patients were drained because of the fear of bile peritonitis; and, as we demonstrated in both cases, the wounds drained bile profusely for many days following the operation.

ELDEN C. WECKESSER (closing): I wish to thank Dr. Coleman and Dr. Siler for their comments and to point out the fact that our cases may have given a little misrepresentation of the problem in that two of them died. Not all patients whose cases are reported in the literature die by any means.

I think that the amount of small bowel that can be successfully removed, not interfering with the nutrition of the patient, is a very variable thing. Even though usually 30 to 50 per cent may be the limit, there are patients that will tolerate a very extensive resection. Dr. Siler's patient had only 18 inches of jejunum remaining. I think that is a practical point we should remember; and when we come across these very extensive cases, we should go ahead and resect them in the hope that they might fit into the category such as Dr. Siler's case.

I was interested in Dr. Sanders' remarks regarding tween-80. I am glad that he had better results than we did. I would mention one thing: In two cases in which we used it, there was a drop in white count and that is something to watch for in further use of the drug.

VINTON E. SILER (closing): I would like to thank all those who participated in the discussion.

To answer Dr. Johnston's question, I agree that one may see air any place in the retroperitoneal space from rupture of the duodenum due to trauma. As pointed out by Sperling and Rigler in 1937, the air usually localizes to the retroperitoneal spaces in the right gutter. They stressed particularly that when one sees air about the right kidney, this diagnosis should be considered. I think there is no limit to where air may go or even the amount of air that may be present. Therefore, one may see small bubbles of air in any spot and flat and upright roentgenograms of the abdomen should always be taken.

With respect to Dr. Sanders' question, I did not have time to discuss the anatomy of the duodenum but we all know that it is a retroperitoneal organ and one part of the gastrointestinal tract which is subjected to fracture. The first portion is free but the second portion, of course, where the papilla Vater empties into the duodenum, is not so fixed. However, as one approaches the third and fourth portions which traverse the spinal column, the fixation becomes more marked.

In the cases that I have reviewed in this paper the location of rupture has been the junction of the second and third portions and also the third portion itself; occasionally there are reports of rupture of the fourth portion which, of course, is the most difficult to approach surgically.

With regard to injury of the common duct I would say that as one mobilizes the duodenum to the left, one can visualize the duodenal and pancreatic portions of the common duct. I see no reason to extend the incision further into the duodenum and explore the common duct from the interior of this organ. I think you can visualize it adequately on the outside.

With regard to Dr. Mayfield's remarks I agree that the pain may be posterior. We have stressed that point in the paper.

INTRA-ARTERIAL BLOOD TRANSFUSION*

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ONE of the most important considerations in the prevention of shock or the treatment of circulatory collapse is appraisal of the disparity between vascular volume and capacity of the vascular system. Certain clinical manifestations, especially an increase in the pulse rate and peripheral vasoconstriction, are important signs in the early stages before a drop in blood pressure occurs, yet there are many conditions under which the vascular volume has decreased to a dangerous level even though blood pressure may be normal. Laboratory procedures such as hematocrit and hemoglobin determinations, while of value in appraising the degree of hemoconcentration in plasma loss or the degree of hemodilution early in hemorrhage, are but milestones in a rapidly changing syndrome. Because of the difficulties encountered in gaining an estimate of the degree of depletion of the vascular volume, work on the intra-arterial administration of blood was begun in 1939. The first patients were treated by the author with intra-arterial replacement in 1939 and 1940.

Intra-arterial blood replacement is based on Pascal's principle, stated as follows, "The increase in pressure on any portion of a confined liquid is transmitted unchanged to all parts of the liquid." Pascal's law applies when pressure is exerted to a confined liquid in a receptacle. A variation occurs in the vascular tree in that the pressure within the arterial system at points distant from the site of injection will be diminished, though slightly, due only to the friction loss against vessel walls. This difference is not considered to be significant. It follows therefore that maintenance of a systolic blood pressure of 120 within the radial artery will result in the maintenance of a systolic blood pressure of approximately 120 throughout the entire arterial tree. If a reservoir containing blood is attached by needle or cannula directed toward the heart to a major artery and the height of the reservoir is adjusted so that the pressure head is equal to the current blood pressure, blood will neither run into the radial artery nor be discharged from the patient into the reservoir. Vasoconstriction may suffice to maintain a normal blood pressure even though vascular volume may be reduced. As vasoconstriction is released blood will be delivered from the reservoir to maintain the blood pressure. Should hemorrhage occur, blood will be supplied from the reservoir to maintain normal blood pressure, the rate of flow from the reservoir being approximately equal to the rate of loss from hemorrhage. A pronounced fall in blood pressure occurs in the presence of coronary vessel infarction. The openings of the coronary vessels are distal to the aortic cusps. Maintenance of adequate blood pressure levels within the aorta by the administration of blood into the arterial tree will perfuse undamaged coronary vessels. In cases of coarctation of the aorta frictional loss of pressure along the walls of numerous small anastomotic vessels results in a lowered bood pressure distal to the constricted aortic segment. At operation after the constricted segment has been excised and an anastomosis has been performed, removal of the aortic clamps may result in a dangerous drop in blood pressure. This hazard may be overcome by administration of blood into the femoral artery in an amount which will ensure a blood pressure in the distal segment equal to that in the proximal segment.

Kohlstaedt and Page[1] in 1943 first demonstrated the value of intra-arterial blood replacement in hemorrhagic hypotension. They found that the removal of 3.3 to 5.9 per cent body weight of blood from dogs was uniformly fatal. Following a sustained hypotension, the intra-arterial administration of all the blood removed resulted in survival of eleven of twelve animals. Under similar conditions the intravenous administration of all the blood removed resulted in survival of six of seven animals. Most importantly, intra-arterial administration of only one-half of the blood withdrawn to produce hypotension resulted in the recovery of fifteen of twenty animals. Only six of twenty animals recovered when the intravenous route was chosen. In 1946 Page[2] reported that intra-arterial blood replacement was advantageous

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in that perfusion of the coronary arteries was accomplished and that deep breathing started soon after intra-arterial blood infusion. He noted further that blood volume could be restored by this route and that latent hemorrhage could be detected early.

Gardner[3] in 1946 withdrew blood to produce controlled hypotension when serious bleeding might be expected or encountered. During intracranial operations a sufficient amount of blood was withdrawn from an artery to reduce blood pressure and the blood was replaced after the hazardous steps had been passed. This same principle was applied by Love[4] and his associates in 1948 during the removal of an intracranial lesion, with a successful outcome. Shaffer[5] utilized the femoral artery for blood replacement in cases of vascular collapse. Kay and Hacker[6] administered blood into the ascending aorta in a case of circulatory collapse due to transsection of the internal mammary artery.

By 1948 intra-arterial blood replacement was being practiced in several clinics. Glasser and Page[7] found that intra-arterial blood administration was an excellent method of resuscitation. Thirty-nine animals subjected to hemorrhagic shock were further bled until breathing stopped for an average of two to eight minutes and the heart stopped beating for two minutes. Intra-arterial administration of blood resulted in resuscitation of 84 per cent of the animals. Fifty-one per cent lived for an average of ten hours and 33 per cent survived indefinitely. Porter, Sanders and Lockwood[8] emphasized the rate of replacement of blood when massive loss occurs. Recovery occurred in eight patients with severe shock when blood was given intra-arterially. The ability to control blood pressure as a safeguard against shock was reiterated. Robertson, Trincher and Dennis[9] presented data on the intra-arterial administration of blood in twelve patients in whom dramatic results were obtained in ten.

Blood has been administered by way of the aorta, femoral, dorsalis pedis, brachial and radial arteries. No complications have been reported in the nature of damage to the arteries as a result of insertion of the needle. Ligation has been practiced in some clinics when the radial artery has been used. It is cautioned that should a complication occur necessitating ligation of the femoral or brachial artery, serious gangrene might result. Sacrifice of the radial artery in the presence of anastomotic palmar arches is not hazardous. Unless an anomaly occurs in which an anastomosis may be absent between the ulnar and radial arteries, utilization of the radial artery may be considered safe provided the period of administration is not prolonged. It is our practice to administer blood by use of the radial artery, recognizing that the centripetal administration results in a perfusion of the arm with blood containing a reduced quantity of oxygen. Pressure at the radial artery should not exceed that of the general circulation for extended periods. It is considered safe to permit the same period of time to elapse as that practiced when operations are done upon the extremity under tourniquet application. Periodically the pressure in the reservoir should be brought to a level equal to or less than the systemic pressure in order that blood with maximum oxygen concentration might perfuse the extremity.

The hazard involved in the administration of blood of low oxygen content within an artery in the distal extremity might be overcome by one or two means, either oxygenation of the transfused blood or the introduction of a catheter into the radial artery of sufficient length to deliver the blood at or near the aortic arch. Attempts to oxygenate blood so far have not been unsuccessful. For example, addition of hydrogen peroxide to drawn blood results in a frothing which reduces the pressure head of the reservoir. The administration of such blood under pressure of air or oxygen is dangerous from the standpoint of air embolism. An apparatus has not been developed which is capable of saturating donor blood with oxygen. The use of intra-arterial catheterization has not been reported to date, yet this seems entirely practical in view of the now commonplace venous catheterizations.

I thought in 1939 that the arterial administration of blood was original with me. So far as I am able to determine, the studies summarized above represent the first application of this method since blood transfusion has become a safe procedure. However, before the days when transfusion was safe, Landois[10] referred to the possibility of infusion by the intravenous route directed toward and away from the heart and the intra-arterial route toward and away from the heart. One practical application of the administration of blood toward the heart by the intra-arterial method was reported by Halstead[11] in 1883. The blood of patients with severe illuminating gas poisoning was removed

from an artery, whipped in the open air and replaced by use of the artery. At this stage of its development arterial administration of blood has been demonstrated to be of value under the following conditions: (1) The rapid replacement of large quantities of blood in cases of severe hemorrhage; (2) the replacement of blood adequate to maintain blood pressure levels in cases of concealed hemorrhage; the amount of blood required to maintain normal blood pressure is found to be approximately equal to the amount being lost; (3) the maintenance of normal blood pressure levels in the presence of impending collapse due to trauma or hemorrhage provides an additional important factor in that surgery may be performed promptly when indicated; this avoids the loss of time required to re-establish a safe blood pressure level before anesthesia or operation; (4) perfusion of patent coronary vessels at a blood pressure of any desired level, in cases of coronary infarction; (5) reduction of blood pressure to any desired level consistent with tissue oxygenation, during the stage of operation in which serious hemorrhage may be expected, with the subsequent return of blood to the circulation after the stage of danger has passed and (6) the production of a blood pressure level in the distal aorta equal to that of the proximal aorta prior to the release of clamps after resection of the aorta in cases of coarctation.

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DISCUSSION

H. Gurth Pretty (Montreal, Canada): Col. Seeley's paper has brought forward many important points but there are some other points I would like to bring out with reference to it. I have been very interested in this subject for the past three or four years and have been studying it, mainly from the point of view of what happens to our blood pressure when we are doing thoracico-abdominal sympathectomies for hypertension. I have been trying to work out ways and means that we can use to control blood pressure during this procedure.

I tried intravenous methods, both blood, plasma and saline. Finally, I discontinued that, believing that we were having a great deal of trouble in controlling our right heart mechanism. The point was finally brought to conclusion when a patient was admitted for sympathectomy for hypertension. It had been worked up thoroughly by the medical staff but she was transferred to the surgical service, we frightened her and she had a coronary attack. I refused to operate and we sent her home and watched her for a period of three or four months. The cardiologist said she was then ready for a sympathectomy. I disagreed. I said if she had a coronary attack under normal conditions, she would have another due to hypotension on the operating room table. He would not believe it. So we tossed a coin and I lost; I operated.

The patient went along perfectly well in the operating room but upon return to the ward she had a coronary attack and died. We had a cardiograph taken at death and we still cannot get our cardiologist to read that graph.

What I am coming back to is this, that if we get a hypotensive patient and do not supply the coronary circulation, we are going to get an artificial coronary attack. Therefore, we began experimenting with drugs which would produce a vasoconstriction of the capillaries and the arteries. We came to the conclusion that by using 5 cc. per 500 cc. of glucose saline, 1 per cent of neo-synephrine in the form of a drip, we could maintain a constant blood pressure of 120 and that, I notice, is exactly the thing we are referring to, I believe that if you have no intra-arterial transfusion on hand, the neo-synephrine drip, running constantly, will help you over a lot of your difficulties. As a matter of fact, we are going into that point and are using more and more of it instead of transfusions.

STUDIES ON SKULL FRACTURE WITH PARTICULAR REFERENCE TO ENGINEERING FACTORS*

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IT is a well known fact that head injury is a frequent cause of death. Investigations made by Crash Injury Research of Cornell University Medical College show that in survivable airplane crashes head injuries are primarily responsible for death. Head injuries also figure prominently in automobile accidents. Medicine and engineering can definitely contribute to a reduction in the severity of accidental head injury by changes in automobile structural design.

Let us briefly consider a few automobile accident statistics. Bodily injuries occurred in a little over 10 per cent of the 45,000 automobile accidents in Detroit during the year 1947 according to the figures furnished by the Accident Prevention Bureau of the City of Detroit. Head, face and craniocerebral injury occurred in approximately 47 per cent of the injured people. The type and severity of the injury received was related to the position or seat occupied by the individual. When the driver had other passengers with him, accidental injury to the driver alone occurred in only 4 per cent of the cases but injuries to the passengers alone occurred in 72 per cent. Both driver and passengers were injured in 24 per cent. (Fig. 1.)

Passengers sitting in the seat next to the driver received injuries most frequently and drivers received the least injuries. Head injuries were most frequently suffered by the passengers sitting next to the driver but body injuries were more common in back seat passengers. (Fig. 2.)

Statistics furnished by the Michigan State Police for the year 1947 show that in rural accidents on the highways head injuries to passengers occurred twice as frequently as to drivers while 67 per cent of all the persons injured received head injuries. It appears that in rural accidents where speeds are greater than in the city head injury is more prevalent. (Fig. 3.)

This brief summary of automobile accident statistics reveals several important factors. One is that the driver gains considerable protection by holding onto the steering wheel, thus preventing his head from being thrown forward into the windshield or instrument panel. This is particularly true in the lower velocity accidents; but it should be pointed out that at high speeds this same device becomes a lethal weapon since the wheel breaks off and the steering column punctures the driver's chest. It is also apparent that the passenger in the front seat next to the driver receives his head injuries by being thrown forward into the windshield or instrument panel. This occurs in both low and high speed accidents. In view of the large percentage of accidental head injuries it would appear reasonable that the engineer first give his attention to the redesign of windshields and instrument panels.

The total injurious effect upon the organism is, of course, due to the absorption of energy by the head and body. One of the fundamental quantities is the magnitude of the energy and its rate of absorption resulting in definite injury. With these data available, by proper design of windshields, instrument panels, etc., a decrease in the number and severity of injuries in automobile accidents is likely. It is the purpose of this article to present some of this fundamental information. The procedure used to determine the amount of energy necessary to produce fractures of the skull in cadaver heads will be presented.

Parts of our investigations have dealt with the skull itself and have been carried out with the aid of stresscoat. The nature of the deformation (whether primarily due to direct stress or bending) from a blow at right angles from the surface of the skull in any location has been determined by coating the skull inside and out with stresscoat lacquer. The energy of the blow was controlled by dropping the skull of known weight through a measured distance onto a polished steel slab weighing 160 pounds. After the blows were struck, the skulls were

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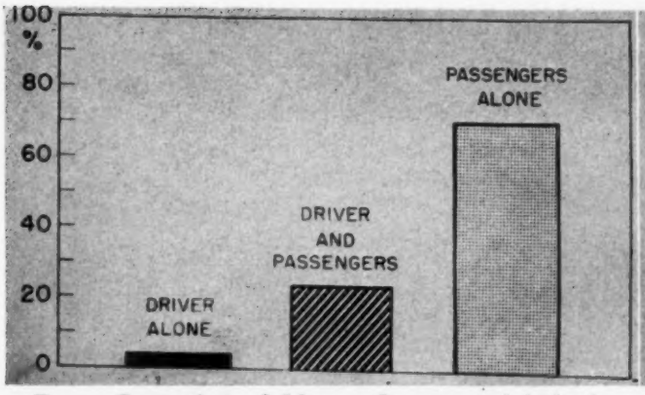


FIG. 1. Comparison of driver and passenger injuries in 289 accidents in Detroit, September, 1947.

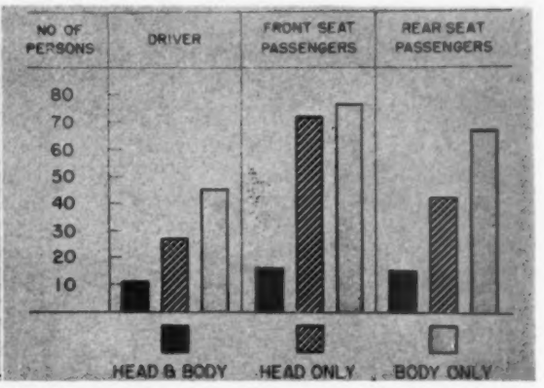
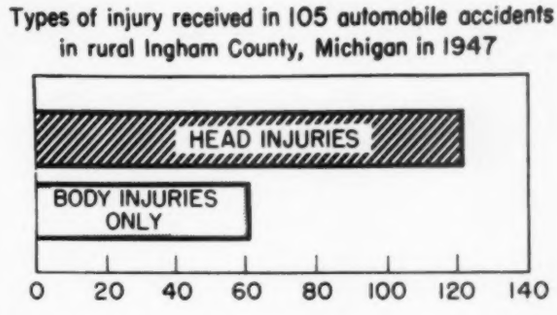


FIG. 2. Comparison of types of injury suffered by occupants of automobiles in 289 accidents in Detroit, September, 1947.

sawed in two on a band saw in order to permit the interior patterns to be developed with red dye etchant and photographs of both the interior and exterior patterns were obtained. The type of interior pattern obtained was remarkably consistent no matter where the blow was struck. Inbending was always indicated directly under the point of impact. If the blows were sufficiently severe, cracks in the lacquer on the interior surface invariably radiated out from the point of impact. The extent of the cracks was always greater in the direction of the maximum radius of curvature, that is, along the flattest portion of the skull. With an adequate blow cracks also formed on the outer surface of the skull dovetailing with the interior pattern and indicating an outbending of the bone.

As a result of the stresscoat tests we find that linear fractures are, in general, initiated on the external surface of the skull due to outbending at a considerable distance from the point of impact. (Figs. 4 and 5.) After initiation the fracture line runs toward the point of impact and also extends in the opposite direction. The fracture line generally reaches the point of impact since after its initial inbending this area rebounds and becomes a region of maximum tensile stress on the external surface as seen from strain gauge studies.

In order to verify the results obtained from the stresscoat tests and to determine the significance, if any, of the hair, scalp and skull contents, impact tests were made on fifty-five completely intact human cadaver heads obtained from the Anatomic Laboratory of Wayne University. Blows were delivered in four positions: midfrontal, anterior interparietal, mid-occipital and right or left posterior parietal. The results of these tests confirmed the stresscoat test predictions and indicated that the presence of hair, scalp and skull contents did not alter the position of the resulting fracture. (Fig. 6.) Further confirmation was obtained by examination of clinical fractures by means of x-rays



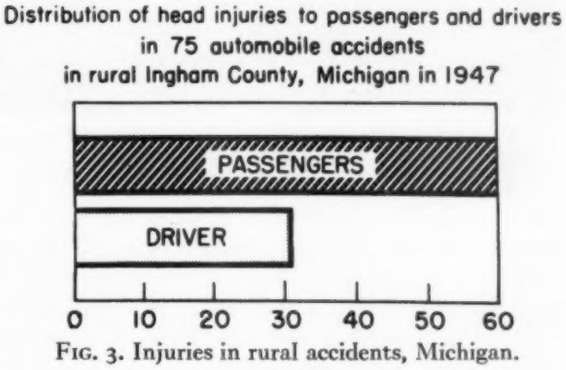


FIG. 3. Injuries in rural accidents, Michigan.

when the position of the blow was definitely known. The point of the blow was indicated by means of a radiopaque wire when the x-ray photograph was made. (Fig. 7.)

While the tests of intact cadaver heads confirmed the predictions of the stresscoat tests regarding location of fractures, they also gave us some information of greater value which may be applied to provide greater safety in engineering

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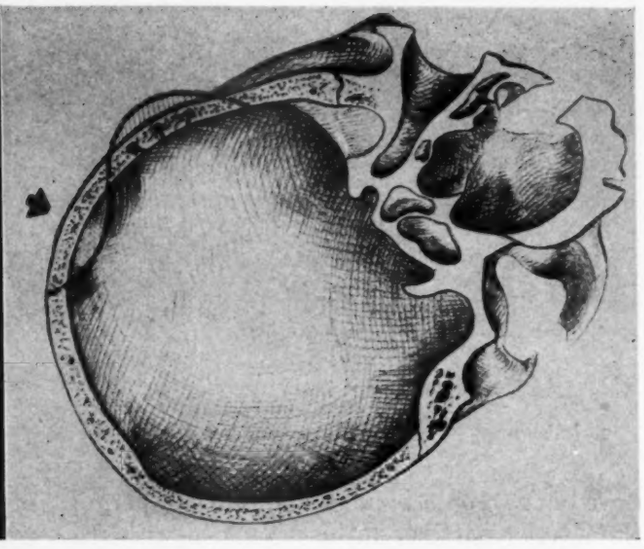

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FIG. 4. Stresscoat pattern due to posterior parietal blow indicates region of initiation of fracture.
FIG. 5. Diagrammatic sketch illustrating the inbending of the skull at the point of the blow with simultaneous outbending in the temple region.

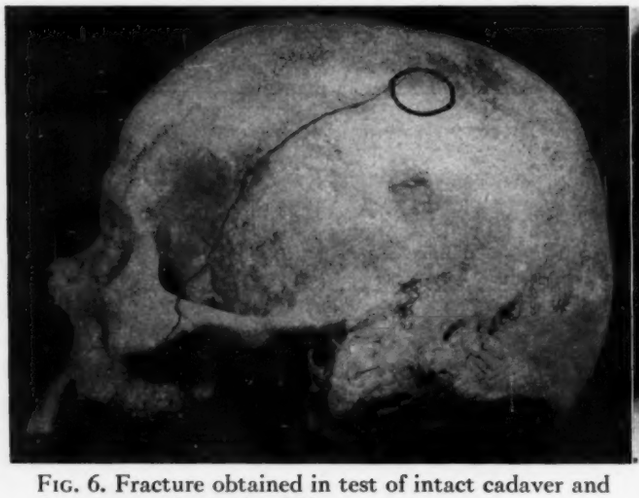

FIG. 6. Fracture obtained in test of intact cadaver and due to posterior parietal blow.

Fig. 7. Clinical x-ray photograph of fracture due to posterior parietal blow.

design. This information is the amount of energy and its time of absorption required to fracture the human skull. Since the weight of each head was obtained (weights varied from 7.3 to 14.6 pounds) and the distance through which it was dropped onto a heavy steel slab was measured, the energy absorbed by the head was easily determined. (Tables I to IV.)

One of the surprising results of these tests of fifty-five cadaver heads is the fact that after enough energy has been absorbed to produce a single line fracture, very little more is required for multiple fractures and complete destruction of the skull. While this might reasonably have been deduced by giving a little thought to the problem, it was a matter that had not previously been considered.

Energy requirements for the production of a single fracture with blows in four different positions varied from 400 to 900 inch pounds while in one case fracture could not be produced with an application of over 1,000 inch pounds of energy. The difference in the average amount of energy required for fracture with blows in various positions did not appear to be of importance in view of the large variations in energy requirements in any one position. The average energy necessary to produce a single linear fracture with blows in the frontal midline region was 571 inch pounds; in the back midline

region, 517 inch pounds; in the top midline region, 710 inch pounds and in the region above the ear on either side, 615 inch pounds; but the energy necessary for fracture in the mid-frontal midline area alone varied from 425 to 803 inch pounds. The average energies for complete destruction were very close to those required to produce single linear fracture. Due to the small number of heads tested, the averages obtained for each position are obviously not significant but the fact that the least energy required for fracture was in the neighborhood of 400 inch pounds for six of the heads tested is of importance.

TABLE I

EXPERIMENTAL SKULL FRACTURE, MID-FRONTAL DECELERATION IMPACT

No.	Energy in Lb.	Scalp Thickness (mm.)	Weight as Dropped (lb.)	Weight Dry (lb.)	Distance Dropped (in.)	Velocity of Impact (ft./sec.)	Race	Fracture*
43	415	4	10.38	1.23	40	14.7	W	II
44	425	4	10.63	1.20	40	14.7	W	I
36	484	5	11.0	1.48	44	15.4	W	I
39	556	5	12.63	2.18	44	15.4	C	II
4	803	4	14.38	1.64	56	17.4	W	I
41	496	5	12.38	1.38	40	14.7	W	III
40	420	3	10.0	1.11	42	15.1	W	III
42	440	3	11.0	1.34	40	14.7	W	III
35	465	4	11.63	1.28	40	14.7	W	III
38	497	7	14.63	2.20	34	13.5	W	III

* Fracture numbers:
I, single linear fracture
II, two linear fractures
III, stellate fractures

TABLE II

EXPERIMENTAL SKULL FRACTURE ANTERIOR INTERPARIETAL DECELERATION IMPACT

No.	Energy in Lb.	Scalp Thickness (mm.)	Weight as Dropped (lb.)	Weight Dry (lb.)	Distance Dropped (in.)	Velocity of Impact (ft./sec.)	Race	Fracture*
17	608	6	14.13	1.78	43	15.2	W	I
13	633	5	11.5	1.60	55	17.2	Filipino	I
6	699	4	10.13	1.33	69	19.3	W	I
5	845	4	12.25	....	69	19.3	C	II
12	851	6	10.38	1.89	82	21.0	C	II
20	902	6	11.0	1.69	82	21.0	W	I
9	630	1½	10.5	1.28	60	18.0	W	II
22	677	2	8.25	1.25	82	21.0	W	III
19	681	4	12.38	1.63	55	17.2	W	III
7	653	4	9.06	1.38	72	19.7	W	III
1	843	4	8.78	1.76	96	22.8	Not obtained	III
21	591	4	8.69	1.15	68	19.1	W	III
15	666	2½	9.25	1.15	72	19.7	W	III
16	667	5	10.75	1.14	62	18.3	C	III
25	686	3	9.94	1.41	70	19.5	W	III
10	704	5	11.0	1.37	64	18.6	W	III
11	707	4	10.88	1.77	65	18.8	C	III

* Fracture numbers:
I, single linear fracture
II, two linear fractures
III, stellate fractures

This large variation in energy requirements from one head to another is due to difference in thickness of scalp and skull, shape of skull and slight change in position of blow. Since fractures of the skull itself have been produced with as little as 40 inch pounds of energy in the dry skull in contrast to 400 or more inch pounds in the cadaver head, the energy-absorbing capacity of the scalp and its protective function is clearly evident.

That some difference will exist between the amount of energy required to fracture a cadaver head and a living one seems probable but it is believed that this difference is of the same order of magnitude as that due to variations in the other factors such as scalp thickness. This belief is based on consideration of the occasional accidental fracture sustained in a baseball game when the batter is struck by a fast pitch. Using 100 feet per second as the speed of a fast ball (weight 5 ounces) thrown by the pitcher, its kinetic energy will be 580 inch pounds. Some of this energy will go into deforming the ball and accelerating the head; but on the other hand, since the ball is curved instead of a plane surface, somewhat less

TABLE III

EXPERIMENTAL SKULL FRACTURE OCCIPITAL DECELERATION IMPACT

No.	Energy in Lb.	Scalp Thickness (mm.)	Weight as Dropped (lb.)	Weight Dry (lb.)	Distance Dropped (in.)	Velocity of Impact (ft./sec.)	Race	Fracture*
45	400	5	10.0	1.27	40	14.7	W	III
31	468	8	11.69	1.74	40	14.7	W	II
32	502	6	11.44	1.68	44	15.4	W	I
23	504	7	10.5	1.93	48	16.1	C	II
33	532	8	10.63	1.63	50	16.4	W	I
26	457	3	9.94	1.16	46	15.8	W	II
30	502	6	12.25	1.32	41	14.9	W	II
24	548	4	8.31	1.73	66	18.9	W	II
27	419	3	8.38	1.02	50	16.4	W	III

* Fracture numbers:
I, single linear fractures
II, two linear fractures
III, stellate fracture

TABLE IV

EXPERIMENTAL SKULL FRACTURE POSTERIOR PARIETAL DECELERATION IMPACT, RIGHT OR LEFT

No.	Energy in Lb.	Scalp Thickness (mm.)	Weight as Dropped (lb.)	Weight Dry (lb.)	Distance Dropped (in.)	Velocity of Impact (ft./sec.)	Race	Fracture*
48	845	5	11.13	1.87	76	20.2	W	II
47	840	3½	12.0	2.19	70	19.5	W	III
49	584	5	7.3	1.33	80	20.7	W	III
2	907	4	12.6	1.59	72	19.7	Not obtained	III
46	482	4	9.63	1.41	50	16.4	W	III
50	855	7	11.25	1.61	76	20.2	W	III
51	675	4	10.38	1.60	65	18.8	C	II
53	650	4	12.03	2.22	54	17.0	W	I
54	579	4	9.65	1.43	60	18.0	W	I
55	475	2	8.63	1.68	55	17.2	W	II

* Fracture numbers:
I, single linear fracture
II, two linear fractures
III, stellate fracture

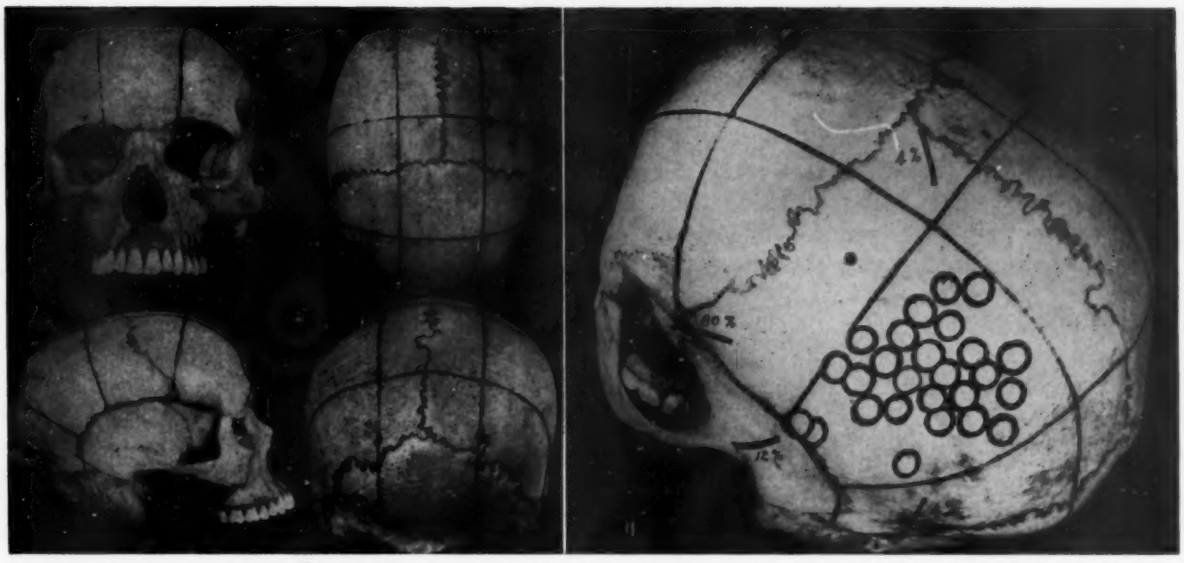

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FIG. 8. Photograph of skull showing subdivision of the surface into twelve areas for the study of the effect of blows in each area.

FIG. 9. Composite effect of blows to twenty-five skulls in the left parieto-occipital region showing percentage variation in position of fracture line initiation; fractures will extend to point of blow from regions indicated.

energy should be required to produce fracture since the area of contact is more localized. The fact that this energy falls in the range of values obtained in these tests indicates that the results obtained apply with equal validity to the living human head.

It might be well at this point to note that there is no direct correlation between the severity of cerebral damage and linear skull fracture; that is, a fatality may result due to concussion without any skull fracture occurring. It is also true, however, that skull fracture may occur without any damage to the brain. The fact that in some cases skull fracture was obtained with as little as 400 inch pounds of energy while in another case over 1,000 inch pounds of energy were absorbed by the head without a fracture may be of significance in explaining these phenomena. It is certain that if the accidental input of energy into the human head can be kept below 400 inch pounds, a considerable reduction in fatalities and serious injuries will result.

Both the stresscoat tests and the experimental and clinical fractures have shown that some variation in the position of the fracture is to be expected with a blow in a particular location. This is logical because of variations in the shape and thickness of skulls and slight variations in position of the blow. This variation in position of the fracture line from one skull to another with a blow in a given location appears to be most pronounced when the skull is struck in the frontal midline region. In some skulls the fracture will appear along the midline above the bridge of the nose. In others it will extend toward the point of impact from the supra-orbital notch above the right or left eye and occasionally it will extend laterally from the temple toward the region of impact.

In order to investigate the degree of this variation a test procedure involving sixty-two skulls was outlined. The top of the head was divided into twelve areas as shown in Figure 8. Each of the sixty-two skulls received a blow in each area thus defined and the stresscoat pattern was obtained. Figure 9 shows an example of the results obtained. This region, the left posterior parietal area, shows about the least variation in the predicted position of the fracture line. The figure includes the results of tests of sixty-two skulls and shows how the position of the blow is varied from skull to skull to cover the entire area.

On the basis of this study it should be possible to predict the position of the fracture line fairly accurately when the location of the blow is known; or if a fracture line is found on the x-ray film, the position of the blow producing it may be determined.

Since the time of absorption of the energy is also an important factor, the electric SR-4 strain gauge was used to obtain this information. The bone was exposed in the temple region of

two heads and SR-4 strain gauges were cemented across the paths of the expected fracture lines as predicted from the stresscoat tests. Blows were to be struck on the side of the head above the ear. When the skull was dropped, it struck a switch fashioned from a piece of brass shimstock on the surface of the steel slab. This switch was connected to one beam of a two-gun cathode ray tube and indicated the initial contact of the head with the steel slab. The other beam was controlled by the strain gauge connected in a simple potentiometer circuit. In one test the fracture occurred at the end of the gauge but in the other we were fortunate enough to have the fracture pass through the center of the gauge, thus opening the circuit. The elapsed time from the instant of contact of the head with the slab until the skull began to deform in 0.0006 second. The bone itself became deformed during an additional period of 0.0006 second until fracture occurred.

In conclusion we would like to point out that the engineer normally thinks in terms of margin of safety regarding the strength of materials used in structures and machines he designs. We trust that this information regarding the maximum tolerance of the human head to absorption of energy may prove of value to the engineer in his attempts to provide the greatest possible margin of safety against injury to persons when these same structures and machines are subjected to accidental damage.

ROLE OF THE UPPER CERVICAL ROOTS IN THE PRODUCTION OF PAIN IN THE HEAD

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Cincinnati, Ohio

THE concept that pain in the head and/or face might arise from disease in the neck is not new.[1] Many writers have referred to this possibility.[12,13,16,19,21,23,25,28,33] Similar symptoms, however, have been thought by others to arise from lesions of the autonomic nervous system, for example, the sphenopalatine ganglion,[36–38] the geniculate ganglion,[20] the vidian[39,40] and greater superficial petrosal nerves,[11] the cervical sympathetics, etc.[4–7,10,15,26,27] Vasodilatation due to histamine sensitization of the vascular tree has received wide attention.[17,18] Nevertheless, the etiology of hemicranial pain, migraine, atypical facial neuralgia, histamine cephalalgia, the post-concussion syndrome, etc., has remained obscure and the results of therapy disappointing.

The recent clinical investigations of Raney and his associates[29–33] have shown that disorder of the cervical discs may give rise to pain in the head and face. Their attention has been directed to the middle and lower cervical spinal roots. We have been interested in the upper cervical spine and in particular the sensory root of the second cervical nerve.

This article is based on the data of eleven patients who suffered with recurring attacks of severe hemicranial pain in the head and/or face and who have been treated either by (1) avulsion of the greater occipital nerve; (2) intraspinal section of the sensory root of C-2 or (3) section of the sensory roots of C-2 and C-3.

These cases may be divided roughly into two groups, namely, those cases in which symptoms followed definite trauma to the neck and cases in which symptoms of the same character were present without a definite history of initiating trauma. The eight patients whose symptoms followed trauma have been relieved or greatly benefitted by interruption of the upper cervical nerves. Those in which almost identical symptoms were present but without trauma have not been relieved.

It is our purpose in this article to describe the anatomic basis upon which rests the concept that upper cervical root disease might initiate this syndrome, to present the clinical data of these cases and also to present certain data concerning the dermatomes of the upper cervical roots as they have been elicited following operation.

ANATOMY

The articulations of the upper two cervical vertebrae vary remarkably from the remainder of the movable spine. They connect by two laterally and one centrally placed synovial joints. The first and second cervical nerve roots emerge behind the lateral articular masses. The roots, however, are not protected posteriorly by pedicles and facets which elsewhere in the vertebral column complete the root canal.

Their respective ganglia, instead of occupying intervertebral foramena, lie upon the vertebral arches of the axis and the atlas. These nerves course laterally and slightly upward and soon divide into two primary divisions. The anterior primary ramus of the first cervical root, after emerging from the vertebral canal, passes over the posterior arch of the atlas and curves forward around the lateral aspect of the upper articular process of that vertebra. That of the second passes between the arches of the axis and atlas. The posterior primary ramus of C-2 passes backward and gains access to the soft tissues of the neck after passing between the posterior arches of the axis and atlas.[3]

There is relatively little motion between the atlas and the occipital bone; and since the sensory component of C-1 is so rarely present, it is unlikely that this root often plays a part in the production of symptoms. The joint between the atlas and axis, however, is highly movable and the anterior primary ramus of C-2 is subject to unusual stress, even under normal circumstances. The posterior primary ramus of C-2, which continues into the scalp as the greater occipital nerve, emerges between bony surfaces and is capable of being crushed or traumatized by any movement of the head which would tend to approximate these bony

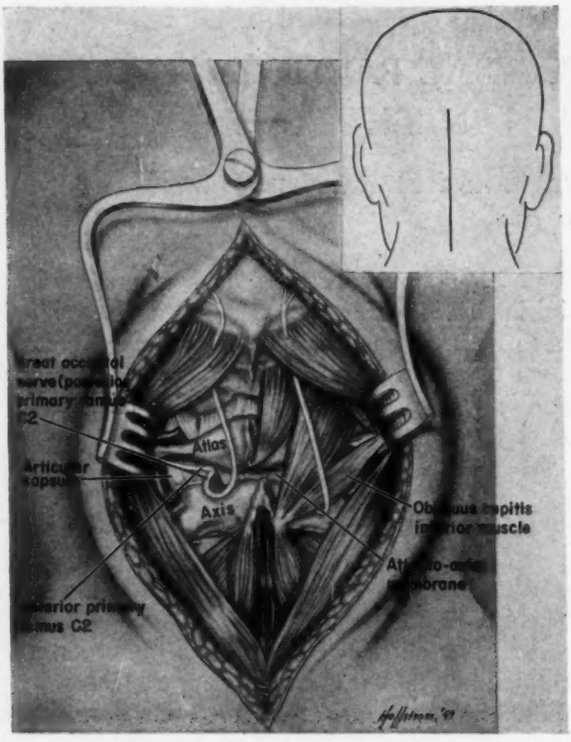

FIG. 1. Artist's drawing of dissection of neck showing relation of the second cervical root to the posterior arches of the first and second cervical vertebrae; muscles denuded on the left side.

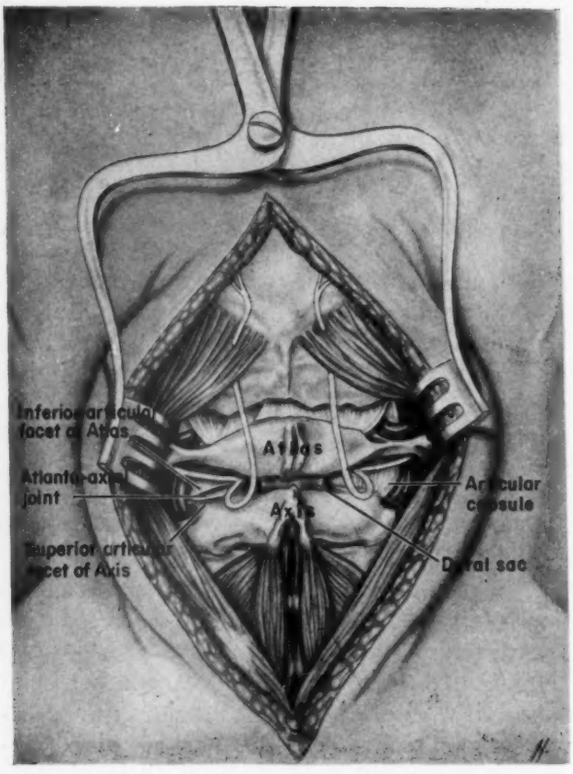

FIG. 2. Relation of the second cervical root to articular facets and rami of first and second cervical vertebrae.

surfaces. Observations of the movements of this joint during manipulation in a cadaver demonstrated that alterations of posture are capable of traumatizing the second cervical nerve.

The third cervical nerve is well protected within its bony canal and seems to be no more vulnerable to injury than any other root.

With rotary motions of the head there is tremendous excursion of the articular facets of the atlanto-axial articulations. The lower atlantal facet on the side to which the face presents slides posteriorly and toward the midline until it is almost off the axial facet and impinges directly on the superior margin of the arch of the axis. If unusual force were applied with the neck in this position or if the nerve ran an aberrant course, crush injury could occur at the point at which the atlantal facet strikes the lamina of the axis. This motion also appears to increase the distance that the anterior primary ramus of C-2 must traverse to leave the spine and if sudden force were applied, stretch injury of the anterior primary ramus of C-2 might occur. On the opposite side, for a distance of approximately 25 mm., from the midline of the axis the arches of the atlas and axis are in contact and actually compress between them the emerging posterior primary ramus of C-2. In addition the upper articular facet of the axis on this side makes contact with the arch of the atlas and appears to compress the anterior primary ramus. (Figs. 1 to 3.)

This peculiar vulnerability of the second cervical root to trauma comprises the anatomic basis upon which this article rests. Within the normal range of motion of the neck the second cervical nerve probably is not vulnerable to trauma. However, if added force were applied to the neck when it was already at the limit of normal range, damage to this structure could occur. Thereafter, once diseased it is believed that normal motions of the neck are capable of maintaining the nerve in a painful state.

When one considers that the second cervical root supplies sensation to the major portion of the scalp and overlaps considerably into the face area in connection with this peculiar vulnerability to trauma, it seems reasonable to assume that this root may be responsible in certain instances for unilateral head and/or face pain. It was upon this thesis that the cases which comprise the material for this report were investigated and later brought to operation.

The patients with whom we are concerned in

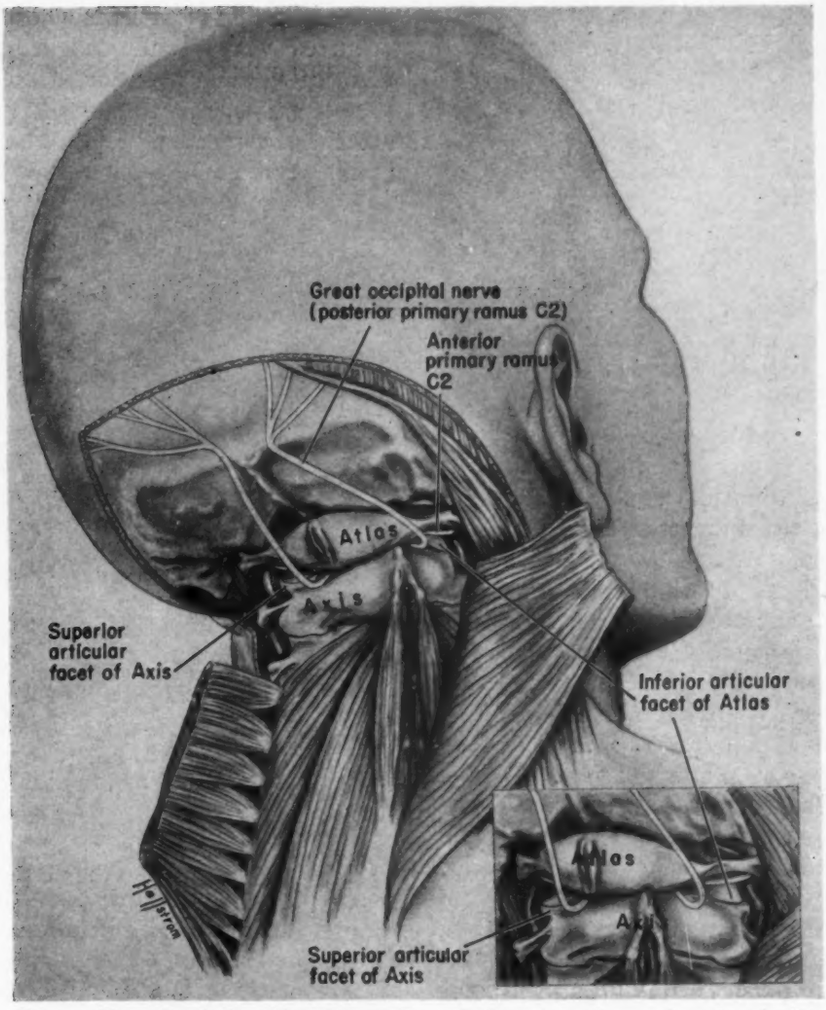

FIG. 3. Altered relationship of second cervical root to the rami and articular facets of the first and second cervical vertebrae with the face rotated to the right and the head extended. (Insert, oblique view of same exposure.)

this article without exception presented themselves with the complaint of recurring severe bouts of pain. Usually the bouts involved one side of the head and always the same side. Occasionally, when an attack was most severe, the pain might spread to involve the entire head. For the most part the pain was initiated in the suboccipital region but radiated to the vertex, the temporal area and usually to the area about the eye. The attacks were prone to come suddenly. They were very likely to occur at night and were often associated with tearing of the eye, flushing of the face, alteration of sweat and at times occlusion of the nasal passage on the side involved. In some of them there were lancinating pains into the face, usually about the lower jaw. When the pain occurred about the lower jaw, it was described as superficial. The pain which was referred to the eye usually was described as a deep, aching pain. In certain patients the pain was referred to the region of the ear but this was less intense than the suboccipital, temporal and eye pain. Many of the patients were conscious of numbness and tingling of the parieto-occipital scalp.

The majority of the patients had been well until they sustained an injury in which the neck was forcibly wrenched. When this group was quizzed, it was brought out that there was more or less constant discomfort in the suboccipital region on the side involved but that they had come to accept this as normal, the severe paroxysms being the issue of chief concern.

Certain of these patients complained of vertigo and a sense of giddiness during the severe paroxysms. Two patients experienced vomiting during the most severe bouts. The

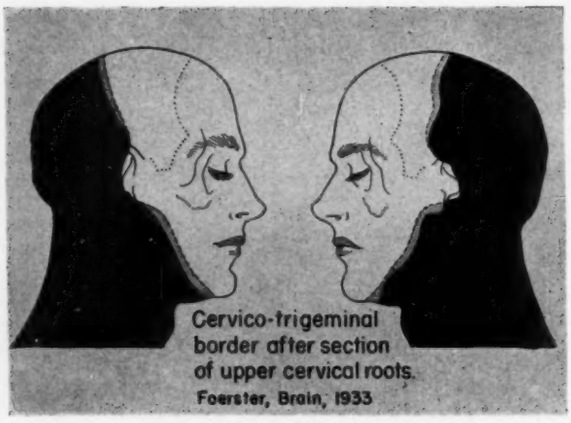

FIG. 4.

attacks varied in duration from a few minutes to several days, the majority lasting from two to three hours.

The three patients in this group who gave no history of injury antecedent to their symptoms had not been conscious of the continuous discomfort in the neck.

If the patients were examined during a severe paroxysm of pain, they appeared acutely ill. There always was exquisite tenderness over the course of the greater occipital nerve and over the point of emergence of the second and perhaps the third cervical roots on the side involved. Rotary motions of the neck, particularly maneuvers of hyperextension and rotation of the occiput to the painful side, would exaggerate the symptoms. Examination with the scratch test[22] usually demonstrated sensory loss in the second and perhaps also the third cervical dermatome. Manual traction on the head occasionally would give transient relief. When the second cervical nerve root was anesthetized with procaine, the pain abruptly ceased and infiltration of the region of the greater occipital nerve with procaine would also interrupt an attack but less abruptly and less completely.

If the patients were examined in an interval between attacks, there was pain and tenderness along the course of the greater occipital nerve. If pressure was applied firmly over the point of emergence of the second cervical root, the characteristic pattern of pain was produced for the duration of the pressure. Usually it could be produced by hyperextension of the neck or rotating the occiput to the painful side. The symptoms could not be produced when similar maneuvers were applied to the symptomless side.

In the group of patients whose symptoms had occurred without antecedent trauma, almost identical findings were present but anesthetizing the second cervical root would not interrupt an attack. It tended to lessen the patient's pain but it never could be abolished completely.

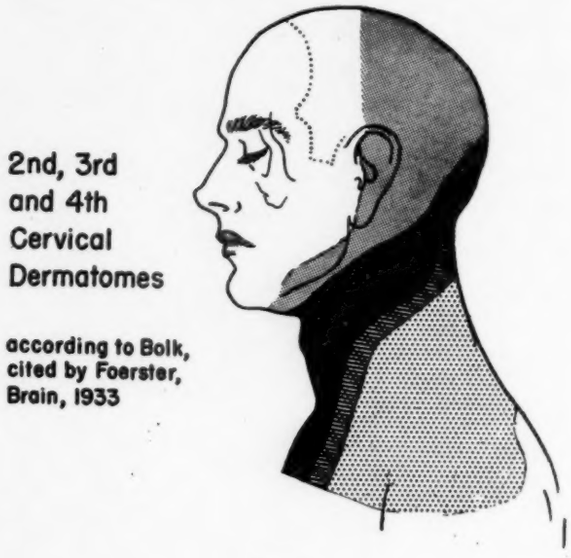

FIG. 5.

The referral of pain from the occipital region into the vertex of the scalp and temporal area when the second cervical root is traumatized is readily understood since this nerve root carries the major sensation to these areas. The referral of pain into the face and the secondary autonomic signs such as lacrimation, obstruction of the nose, etc., are more difficult to explain.

Sherrington's method[34,35] of determining "remaining sensibility" which consisted of cutting three dorsal roots above and below a single root to be studied (in the monkey) indicated extensive overlap of individual dermatomes. Foerster's[8] application of this method in human beings produced the first map of human dermatomes and revealed wide overlap of individual areas. Sherrington's experiments with the macaque[34,35] showed considerable overlap of the trigeminal area by the cervical segments. Zander's[42] anatomic dissections demonstrated terminal filaments of the cervical nerves in all but the central portion of the face, a small area which was designated by Lewy[24] as "the pure trigeminal field." Woolsey, Marshall and Bard[41] have shown in investigation of cortical sensation in the monkey wide overlap of the occipital distribution of the upper cervical nerves by the trigeminal, with supply

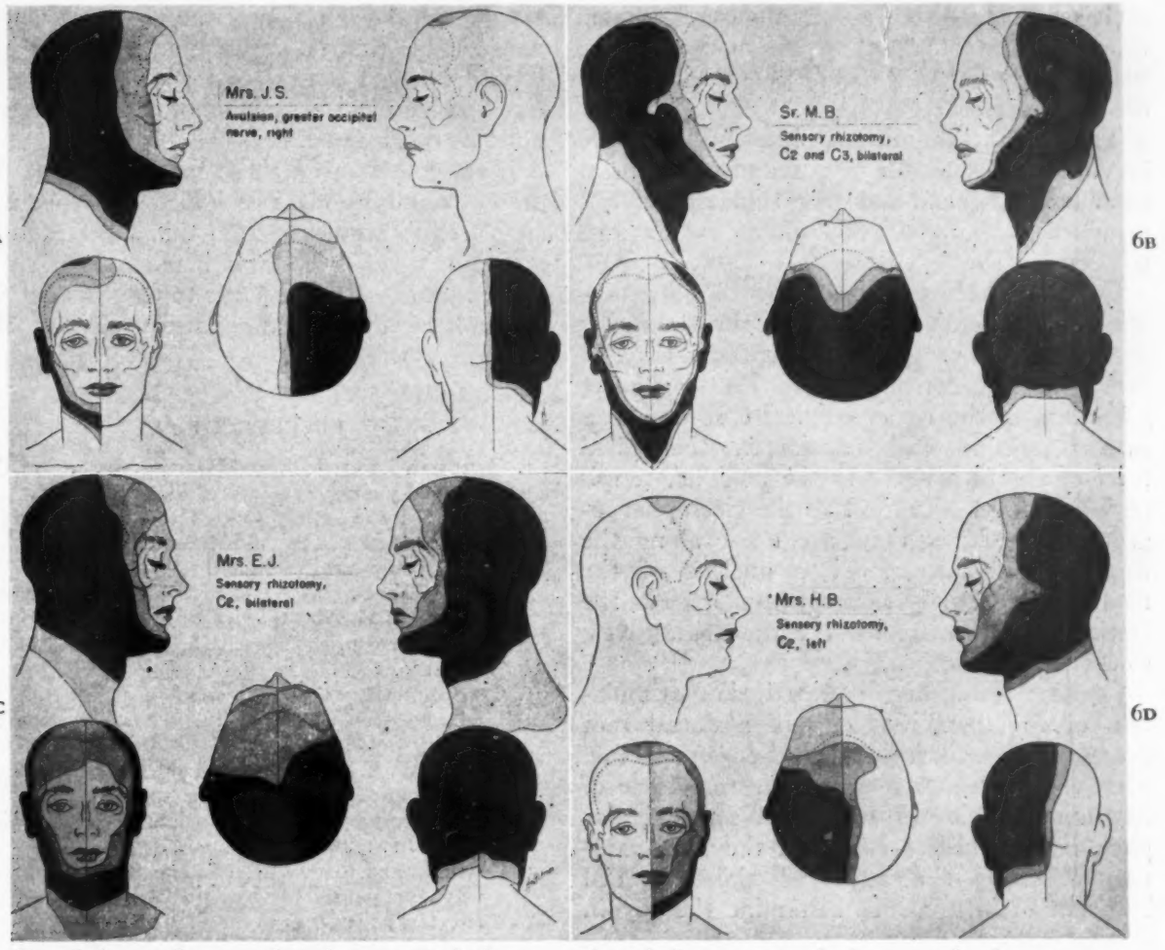

FIG. 6. Areas of sensory loss demonstrated after operation; dark areas, anesthetic except for deep pressure and occasional islands of pain; light areas, diminished pain sensation. A, lower half, after avulsion of greater occipital nerve, right; note that sensory loss extends past midline and along the area inferior to the mandible; B, note relative escape of face in this case as compared to (C) where C-2 was sectioned bilaterally; D, of special interest because of overlap to opposite side and extensive involvement of face area.

to the entire head and in turn the trigeminal overlapped completely by the cervical nerves.

It appears, therefore, that direct anatomic pathways exist by which pain impulses from the cervical region may reach the trigeminal area.

The sensory pattern that followed section of C-2 or section of C-2 and C-3 in our cases demonstrated more extensive overlap of the trigeminal field than Foerster's and Bolk's[9] published studies. (Figs. 4 and 5.)

The residual sensory loss after section of C-2 or C-2 and C-3 shows other peculiarities which are too constant to be dismissed as rare variants. Complete anesthesia was not produced in any of our cases by section of C-2 or C-2 and C-3. The sensory loss was relative and throughout there were numerous islands of pain preservation. Touch was present over the entire area. There was an overlap to the opposite cervical field in several cases and in some instances it extended for a distance of 3 to 4 cm. (Fig. 6.)

We made numerous attempts to reproduce the patient's symptoms by stimulating nerves that were exposed at operation under local anesthesia. In certain instances the pain was referred to the area in question. This was especially impressive when the greater occipital nerve was avulsed. In two patients whose roots were sectioned intraspinally, stimulation of the second cervical root referred pain to the vertex and the region of the eye. Stimulation of the third cervical root referred pain to the region of the ear and neck. For the most part, however, the results of these examinations were not conclusive.

There are possibly pathways in the periph-

eral as well as within the central nervous system to explain the complaint of pain behind the eye and the secondary autonomic phenomena which are often present.

There are communicating branches from the cervical plexus to the vagus and hypoglossal from both C-1 and C-2; the superior cervical sympathetic ganglion has direct connections with cervical roots 1 to 4.[3]

Corbin and Hinsey[2] have shown by degeneration experiments in cats that the ascending sensory branches of the upper four cervical nerves ascend dorsomedial to the substantia gelatinosa of the upper cervical cord and in a similar position with relation to the spinal tract of the fifth nerve in the medulla, terminating at the level of exit of the glossopharyngeal nerve. Connections are made along the way with the intermediate nucleus of the medulla and with the cuneate nuclei, the fasciculus solitarius and the descending vestibular nucleus and tract.

Foerster[8,9] has demonstrated that stimulation of the distal cut end of a dorsal root produces vasodilatation of the dermatome. This vasodilatation may be due to release of histamine within the tissues. If so, a similar phenomenon could account for the vasodilatation observed clinically and the beneficial influence of intravenous histamine therapy in certain cases.

SUMMARY AND CONCLUSION

It is recognized that the follow-up in these cases is too brief to be considered for a final report. It is possible that symptoms may recur in any of those whom we now believe to be well. The striking relief of symptoms which has followed section of the second cervical sensory root in patients with post-traumatic hemicranial pain seems to indicate that trauma to this root may initiate and be responsible for such symptoms. In contrast, there are a group of patients with almost identical complaints whose symptoms did not follow trauma who were not relieved by section of the second cervical root or by avulsion of the greater occipital nerve. It would appear, therefore, that severe hemicranial pain may be initiated by disorder of any of several pathways; and when any one of them is involved, the entire neurovascular tree of one side of the head is affected.

Many phases of this subject require additional investigation, namely, the pathologic condition of the tissues involved and the long-term results of avulsion of the greater occipital nerve as compared to intraspinal section of the second cervical sensory root; also, the role of the first cervical sensory root, when present, must be determined.

If the follow-up in these cases bears out the present observations, it is hoped that this may enable us to segregate from that large mass of individuals suffering from hemicranial pain a certain number that are due to trauma and are transmitted through the sensory root of the second cervical nerve.

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DISCUSSION OF PAPERS BY DRS. GURDJIAN, WEBSTER AND LISSNER, AND HUNTER AND MAYFIELD

Joseph E. J. King (New York, N. Y.): I want to thank Dr. Mayfield and Dr. Gurdjian for their papers. It is the first time I have ever seen such a demonstration of the forces which produce fractures of the skull. All of us are acquainted with the directions in which these fractures run, down toward the middle fossa through the temporal bone from the site of a blow in the parietal region, but I have never seen the mechanics demonstrated so nicely as this morning.

Dr. Mayfield's paper has well repaid me for coming to the Meeting. I recollect well a middle-aged lady whose occipital nerve I have cut and injected three times with relief of pain each time but it always came back. I had a similar experience with a boy at Bellevue Hospital and with still another fellow from Long Island. In each case the pain recurred after having been relieved for several months. Each time the procedure was done under local anesthesia, the nerve with its neuroma being resected and the proximal end injected with alcohol. From Dr. Mayfield's paper I understand that he enters the spinal canal and cuts the dorsal root of C-2. In the future I propose to do the same thing.

Kellogg Speed (Chicago, Ill.): I wish to say a word about Dr. Gurdjian's excellent exposition, and compliment him on his persevering work along this line which he has pursued for a number of years.

If we consider the skull as a sheer globe and omit any study or complication connected with the pathologic condition of the brain and its coverings or the cause of deaths from hemorrhage and so on,

as he has done here, we see that his results show that most of the fractures from a diffuse blow occur in the various fossae, in the base of the skull, because the thinnest bone is at these points and that is where the bone will give if it is going to crack.

Skull fractures from the standpoint of mechanics divide themselves, as he said, into two classes, namely, the indented or punctured fracture from the sharp, rapid blow and the linear or radiating fracture from the diffuse or glancing blow. That goes clear back about 100 years to the old irradiation theory of Iran in which he claimed that the diffused blow was spread around the meridinal axes of this globular skull and when the force reached the base and the thin part of the bone, that is where the bone gave.

I think we should pay every attention to this exposition because it helps us to decide about symptoms and to give treatment.

LAURIE H. MCKIM (Montreal, Canada): I would like to ask Dr. Mayfield to say something about the very interesting group of cases in which there is unilateral pain which is frequently improved and in many cases cured by cocainization of the sphenopalatine ganglion. There is such a group of cases and the subject has been interesting to me for a very long time. I have seen at least three such patients who have been temporarily relieved by this procedure and have been permanently relieved by the clearing up of the associated infection of the antrum.

NICHOLAS J. GIANNESTRAS (Cleveland, O.): It is a very strange thing that although I knew that Dr. Mayfield was doing this work, I had never had the opportunity to discuss it with him. The question that I should like to pose so that it would bring the matter to the attention of all concerns the relationship of this work with the whiplash type of injury to the neck that is received when the passenger or the driver of a car is struck from the rear by another automobile. We see this entity very frequently. The patients come in complaining of severe neck and head pain associated with no visable injury and no roentgenographic evidence of any bone disturbance or disruption. Very frequently these patients have been labeled either as neurotic individuals or malingerers. I wonder whether or not we have not made a mistake and misjudged them in view of this excellent presentation.

E. S. GURDJIAN (closing): I think, as Dr. Speed has emphasized, that there is a difference between skull injury and brain injury; and that skull injury *per se* does not mean that there may be a brain injury and vice versa. As you well know, about 20 to 25 per cent of fatal accidents are due to head trauma unassociated with fracture of the skull, the fatal trauma being due to pressure waves produced in the cranial cavity resulting in intrinsic damage usually around the foramen magnum, causing the death of the individual.

As concerns the previous work on linear skull fracture, it is interesting to review the works of Aran, Felizet, Battle and Bruns. The latter used static loading until one diameter of the skull became shorter than the opposite diameter with resultant fracture. Rowlings, around the turn of the century, also discussed the mechanism of basal skull fracture. It is interesting to note that in all of these studies the position of the initiated fracture is given as being at the point of the blow. Our studies reveal that a linear fracture does not begin at that point. It starts away from the point of impact from outbending of the skull. When the inbended part of the head around the point of impact rebounds, the fracture extends toward the point of impact as well as in the opposite direction. It extends toward the point of impact because although the point of the inbending is initially in compression or pushed in, immediately afterward it rebounds and, as such, represents an area of tearing apart forces; under this circumstance a fracture which has been initiated in that vicinity will tend to go toward that point rather than to the right or the left. We think that the mechanism of linear skull fracture has been properly evaluated with the aid of the stress-coat work.

I enjoyed Dr. Mayfield's paper very much. The problem of hemicrania and the problem of peculiar pains in one-half of the head are seen by neurosurgeons and neurologists very frequently. It is nice that there may be one other method of helping these unfortunate people. As the previous discusser mentioned and as Dr. Mayfield intimated, some of the patients with postconcussion headaches with pain of the top and back of the head may have injured the cervical nerves from the swinging of the head against the neck. It might be interesting to see whether or not blocking of these nerves in some of these cases of postconcussion syndrome might be helpful.

Obviously, this is interesting and good work but one should caution overenthusiasm in the results obtained.

FRANK H. MAYFIELD (closing): I wish to thank each of the discussers.

If I may diverge from my own paper, I would like to commend Doctor Gurdjian for this monumental work. I am sure that because of it our interpretation of the transmission of forces to the brain will be greatly enhanced.

Returning to the discussion of my own paper, I would like to say that I was pleased with Doctor King's comment. We do cut the root intraspinally. It is cut intradurally just proximal to the lamina. It is accomplished by removing half of the lamina of the first cervical vertebra. A dural incision 1 to 2 cm. in length exposes the second cervical root

which can then be picked up on a hook and sectioned. Only the posterior root is divided.

I would like to comment for a moment upon the first cervical sensory root. It is present in less than 10 per cent of patients. We suspect that it may play a part in some of the unexplained pains of the head and face. The skin area that it serves is not understood. We are engaged now in pursuit of the terminus of this root.

Doctor McKim has brought out a very pertinent point, one which I sketched over too rapidly in this paper in the interest of avoiding the gavel. Doctor McKim, there are many disorders which set off hemicranial pain. The sensory supply to the scalp comes from many sources. The chief supply is from the fifth cranial nerve and the second cervical root but apparently the sympathetics from the seventh and ninth cranial nerves also play a part. It would appear that disease of any part of these pathways is capable of initiating a pain syndrome which can involve the entire half of the head. The mechanism of migraine is not understood but it would appear that it is a similar discharge to this. Obviously, however, you cannot cure migraine by cutting any single nerve pathway.

I believe that in the instance which you described there is infection in the nose which initiates a chronic lesion of the sphenopalatine ganglion which from time to time, perhaps under emotional stress, transfers impulses from the autonomic nervous system into sensory fibers which are then bombarded with stimuli of a potential and frequency greater than those which the sensory nerves usually carry; these produce pain.

It is probable that the cases which are initiated by trauma to the second cervical root will be relatively infrequent but we do believe that it offers a possibility of segregating from this mass of people who suffer with hemicranial pain a few who can be relieved by appropriate therapy.

I have had the experience which you have had of seeing many patients whose pain was relieved after cocainizing the sphenopalatine ganglion. Many of you have seen patients with comparable syndromes relieved by histamine therapy. It would appear that the effect of histamine is a secondary one, secondary to the release of histamine within the tissues by chronic stimulation or irritation of nerves. Perhaps the beneficial effect of histamine therapy is one of intoxication rather than true desensitization.

Doctor Giannestras has raised a point upon which I deliberately did not comment for our information is too immature to permit it. I do not believe many patients who suffer with chronic headache or dizziness after trauma may develop these symptoms as the result of trauma to the second cervical nerve. However, we have not been able to prove this. We will pursue it further and bring it to your attention at a later date.

SIMULTANEOUS BILATERAL RUPTURE OF THE QUADRICEPS TENDON

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Upper Darby, Pennsylvania

ALTHOUGH numerous articles have appeared in the literature describing muscle and tendon tears, relatively few of these refer to involvement of the quadriceps tendon. Furthermore, nearly all of the reported cases of quadriceps tendon rupture are of the unilateral variety while the bilateral type is extremely rare.

The first reported instance of a rupture of the extensor mechanism of the leg dates back to the writings of Galin, 130–201 A. D. However, it was not until 1887 that the first successful operative repair was described by Charles McBurney[1] and only four cases had been proven by operation as late as 1889. It might be mentioned that the mechanism of the extensor apparatus of the leg was apparently not fully understood until Poirier[2] in 1899 clarified the anatomy and pathology of the muscle planes of this region.

No accurate statistics are available as to the total number of reported instances of rupture of the quadriceps apparatus up to this time. However, a comprehensive review of the Bellevue Hospital records for the ten-year period between 1924 and 1934 revealed 322 cases of spontaneous rupture by sudden muscle pull. Of these 318 were fractures of the patella and only four were ruptures of the quadriceps muscle, all of the latter being unilateral. The first proven case of bilateral rupture of quadriceps tendon was that of Fry in 1928; in 1935 Meyeiding[3] added one case to the literature as did James[4] in 1938, making a total of three instances reported in the literature to date. In reviewing these three cases it is found that a time interval of from a few minutes to a half hour existed between the ruptures in each instance.

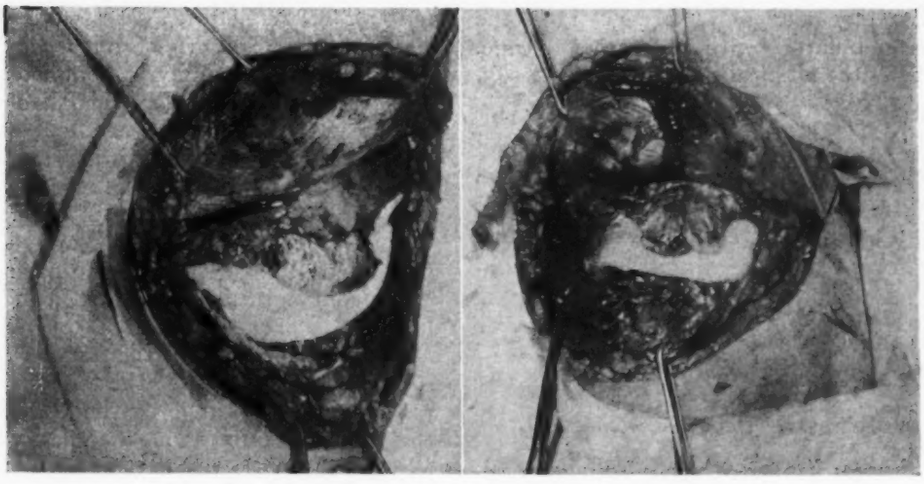
The ruptures of the quadriceps tendon are usually seen after age of fifty, probably a result of weakening of the tendon from obesity and the fibrotic changes of arteriosclerosis, lues, old injury, etc. The actual mechanism of rupture is almost identical in each case. The individual, usually obese, with his knee flexed and his foot in a fixed position, attempts to save himself from falling by violently contracting his quadriceps tendon. A tear of the tendon takes place; he falls to the ground and then finds that he is unable to extend his leg. The characteristic defect palpable above the patella, the loss of extension, subsequent joint effusion and the typical history usually makes the diagnosis an easy one. Treatment is in all cases surgical repair of the defect in the avulsed tendon.

CASE REPORT

G. M., a white male, age sixty-seven, was admitted to the Bryn Mawr Hospital on January 18, 1947. He stated that he had been walking on soft gravel while wearing new shoes, had slipped and attempted unsuccessfully to save himself from falling. He then found that he could not arise to a standing position. He suffered no pain at this time. When assisted to his feet he discovered that he could not remain in an upright position unaided and was completely unable to extend either leg forward as in walking. He was then sent to the hospital by ambulance.

Examination revealed an elderly, obese man apparently in no great discomfort. Physical examination was irrelevant except for the lower extremities. Considerable swelling and contusion of each lower thigh and knee existed and several rather extensive abrasions were present about the knees. The patient experienced no pain whatsoever but moderate tenderness was present on palpation of the region just above each patella and characteristic defects in the quadriceps muscles could be readily palpated. Extension of the lower leg was absent bilaterally.

In view of the presence of the contaminated abrasions, operative repair of the avulsed muscles was deferred for forty-eight hours during which time these were treated and an effort was made to diminish the swelling of the involved area. On January 20, 1947, after sterile preparation of both thighs and legs and with the use of continuous novacain spinal anesthesia, operation was performed. A U-shaped incision with convexity downward and extending to the upper margin of the patella was used to expose the involved area. A large quantity of old blood clot was evacuated from each thigh following which the avulsed



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FIGS. 1 and 2. Show tears in quadriceps tendons; Figure 1, right leg; Figure 2, left leg.

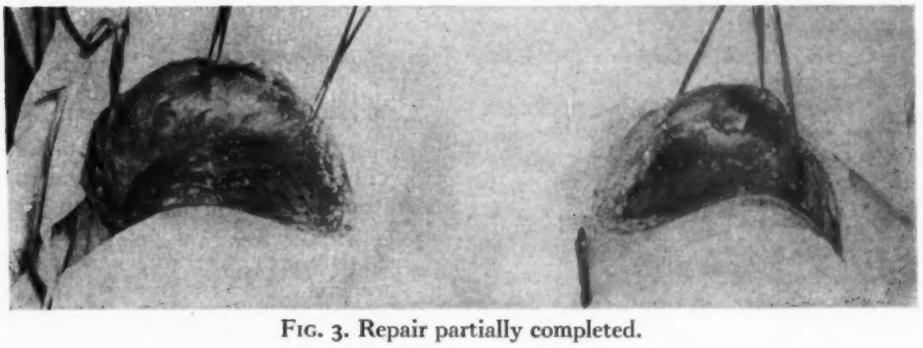
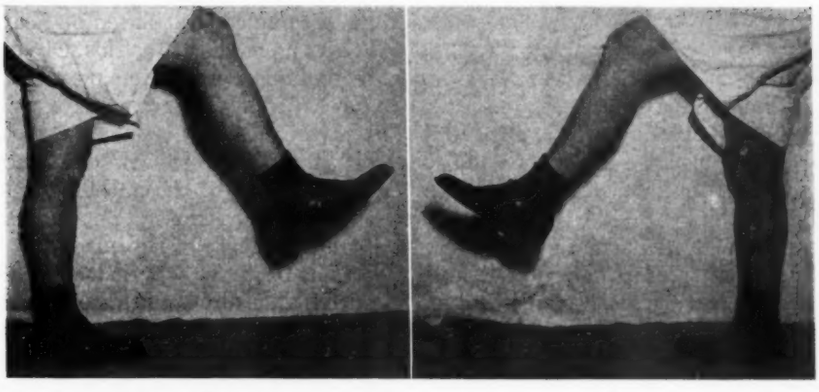


FIG. 3. Repair partially completed.



4 5

FIGS. 4 and 5. Show result six months postoperatively.

muscles were clearly visualized. The tear in each muscle had apparently taken place at a point about 1½ inches above the upper border of each patella. Considerable fraying of the muscle edges existed but no difficulty was experienced in approximating the torn muscles and the repair was effected with interrupted No. 20 black silk mattress sutures. The deep fascia was approximated with interrupted No. 30 silk as was the skin. Immobilization with the use of plaster casts or splints was not used although partial immobility of the knee joints was obtained with elastic bandages. (Figs. 1 to 5.)

Postoperatively, the patient's course in the hospital was uneventful and both incisions healed by primary intention. Penicillin therapy was begun on admission and continued for five days postoperatively. Guarded active and passive motion of the knee joints was begun on the fourteenth

postoperative day and on February 13th the patient was ambulatory with the use of a cane. The patient left the hospital on February 24, 1947.

SUMMARY

1. A brief review of the incidence and of the mechanism of quadriceps rupture is presented.

2. Since no other instance of simultaneous bilateral rupture of the quadriceps tendon could be found in the literature, the case presented was believed to be of interest.

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DISCUSSION

Edgar L. Gilcreest (San Francisco, Calif): Dr. Steiner said that the diagnosis was easy. It is easy if there is complete rupture of a muscle. However, it may be difficult if there is a partial tear or laceration of a muscle. I have seen many of them that had been undiagnosed for months and treated as for a sprain.

I remember one patient in particular who was on horseback. The horse stumbled and fell and the horn of the saddle struck this man's vastus internus, partly tearing it. He was treated for a year conservatively before a diagnosis was made and the muscle repaired.

An interesting point about a tear of a muscle anywhere in the body is that the patient has pain often in the nearest joint. This man complained of pain in his knee and high up in his thigh. Many patients with tears of the long biceps complain of pain in the shoulder and often are treated for bursitis or arthritis and many allied pathologic conditions.

When I became interested in this subject in 1924 and looked up the literature, I was surprised to find such a paucity of articles on the subject. As my interest continued, I finally was able to collect and to report a hundred cases at the Congress of the American College of Surgeons in Chicago in 1933. A partial tear may be completely disabling. I remember one stevedore who had been under treatment for about two years and was about to be rated as having pre-existing arthritis of the shoulder. He had a most interesting rupture of almost the complete tendon of the long head of the biceps. When I opened his arm, I found that most of the tendon had been ruptured from its attachment on the lip of the glenoid and had turned down in a jack-like fashion to become firmly adherent to the belly of the muscle. Some of the cartilage was attached to the tendon. The tendon was freed and sutured to the coracoid process. This patient secured about a 90 per cent recovery.

In another case the tendon had ruptured and had curled up and was encysted as in a cocoon. There was a fine protective sheath all around it; and when I dissected through that, this tendon sprang out as if released by a spring.

I reported fifteen cases of ruptures of the lower extremity in 1932. Every one of these patients had been injured for many, many months. The partial ruptures are the ones that are difficult to diagnose because, as I said, these patients have pain considerably away from where they had the original hematoma. I think many of them should be given the benefit of early exploration under local anesthesia in order to ascertain whether or not a rupture has occurred. Only by doing this will one prevent a contracture of the muscle with resulting impairment of the function of the limb.

Charles F. Wood (Louisville, Ky.): I think we are all to be congratulated on hearing the report of such an unusual case as this. Obviously, the authors are to be congratulated on their handling of the case as well as their exhaustive search of the literature.

I should like to ask one question: Was any specimen sent to the pathologist or was there any evidence of pre-existing pathologic condition in the tissue at the site of rupture?

It has been my experience (which has been quite limited) that any spontaneous rupture of a tendon, at least of a major tendon such as the quadriceps or the tendon achilles, will show evidence of pre-existing fibrotic or calcifying changes. I would like to ask the authors' views on this matter.

Kelvin Magill (Boston, Mass.): Last year at the Boston City Hospital we encountered two cases of quadriceps tears which were unilateral. In both of these cases the tissues at the site of tear showed a great deal of attrition and probably, as the previous doctor just mentioned, the pathologic report, which we did not obtain on these, would verify that impression.

We repaired the tears in both of these cases, using fascia lata strips, interlacing the tissues, and immobilized them in posterior splints for over a

three-week period of time. They both had incomplete extension in approximately two months, as I recall, and were perhaps 15 degrees short of active full extension. This was the best return we could get on our cases in this period of time.

LAURIE H. MCKIM (Montreal, Canada): I would take issue with the gentlemen who have told us that there is always a previous pathologic change in muscle before traumatic rupture. In the last year I have had two cases of rupture of the superficial head of the rectus femoris. They were both in young women under the age of twenty-five; I think one was eighteen and the other was twenty-three. They both occurred in the same way, sprinting. Both women were engaged in athletic competitive races at the time. The muscle was perfectly healthy in every way.

Therefore, I think you may get muscular rupture purely from overstrain without previous pathologic change.

CHILDRESS. I would like to disagree with Dr. Wood on his statement about the pathologic condition pre-existing the rupture and agree with Dr. McKim. I have had four cases of rupture of the tendon achilles which occurred in young men.

My theory is that of Dr. McMaster who has written quite a bit on this in California. He states that the weakest part of the musculotendinous area is at the junction of the muscle and the terminal, at the insertion of the tendon into the bone and also the muscle itself. He makes the statement that the normal tendon will not rupture. That is not true although we have no proof as no slides were made of these cases. But these ruptures occurred in athletes, in basketball particularly, when they would change their minds, leap up in the air, and as the ball changed direction, would land unexpectedly.

The cause of the tear was a snapping. For example, if you take a fishline, you can pull it forward and not get any result; but if you snap it, it breaks. So I believe in many of these cases you get the tear of a normal tendon. I would like to agree with Dr. McKim on that.

HARRISON L. MCLAUGHLIN (New York, N.Y.): Tendon ruptures are biopsied routinely on the Presbyterian Hospital Fracture Service.

To the best of my knowledge there has yet to be a fresh rupture of any tendon, major or minor, in which pathologic sections of the tissues at the site of rupture have not shown an extensive decrease in the collagen in the tendon fibers and a marked loss of nuclei, with enough fibrotic regeneration to suggest, if not prove, that a weak spot antedated the injury.

CHARLES A. STEINER (closing): I would like to thank all the discussers of this paper very much.

Dr. Gilcreest, of course, is perfectly right. In the small partial tears the diagnosis certainly can be overlooked. We were very fortunate in this case in that it was a complete tear on both sides and a very noticeable palpable defect was present. In this case the diagnosis was very easy.

I am afraid, Dr. Wood, that we, too, did not take a pathologic specimen for study. This man was, of course obese and arteriosclerotic. Throughout the literature there seems to be a belief that some pre-existing muscle disease is actually a predisposing course for this injury.

Again I would like to thank the discussers of this presentation for their interest.

THE TEXAS CITY DISASTER*

A SURVEY OF 3,000 CASUALTIES

VIRGINIA BLOCKER, M.D. AND T. G. BLOCKER, JR., M.D.
Galveston, Texas

ON April 16, 1947, at approximately 8:00 A.M., fire was discovered on board the Grandcamp, a French ship (of Liberty type), which lay in the North slip of the Texas City harbor directly alongside Warehouse O (Fig. 1) and across from the Seatrain installation of the Texas City Terminal Railway Company and the Monsanto Chemical Plant. The ship had been loading ammonium nitrate fertilizer for several days and an estimated 2,300 tons had already been placed aboard in 100 pound six-ply paper bags. In addition to the chemical the cargo contained peanuts, machinery, a large amount of sisal twine balls and a small number of boxes containing small arms munitions. Serious efforts at fire-fighting were begun about 8:30, by which time a large number of spectators were gathered in the open area at the west end of the slip and on the dock of the Monsanto warehouse.

At 9:12 A.M. the Grandcamp exploded from detonation of the ammonium nitrate by the fire. The ship itself disintegrated with a tremendous blast, hurling missiles of steel in all directions. Secondary fires in adjacent industrial areas were started by red-hot metal particles and by balls of flaming twine. Meanwhile the force of the explosion had produced a sort of tidal wave about 10 feet in height which rose on to the land from the sides and ends of the slip leaving it momentarily emptied of water, according to several witnesses. The wave was of sufficient strength to float a large hydrochloric acid barge about 100 feet ashore where it came to rest against a pile of wreckage from the ship.

Damage to buildings in the area resulted from the combined effects of blast, missiles and fire. Of the dock warehouses, O was levelled at the outer end where the pier was blown entirely away. In other warehouses roofs were caved in and there was considerable damage from flying débris. At the Monsanto plant, the dock warehouse and southern portion of the polystyrene building, 350 feet from the explosion, were completely devastated as walls and roof were blasted away. Fire immediately followed. No explosion occurred within the plant but release of hydrocarbon compounds added fuel to flame. The steam plant and power house, which were in direct line of the blast, were levelled completely. In the office and service buildings partition walls were demolished and windows were blown out but there were no fires in these two units. The storeroom, instrument shop and laboratory, although shielded by other structures, were destroyed by blast and fire. The various process units were damaged extensively and tankage fires in these areas burned for over forty-eight hours.

The seatrain installation and the grain elevator, both in the direct line of the blast, were left standing in spite of considerable weakening of these structures from concussion and the effect of missiles. Two water tanks in the area, however, were relatively untouched. A grain conveyor leading from the elevator to Warehouse B was stripped of its siding. The Terminal Railway offices and power house were partially destroyed by concussion; the adjacent machine shop was completely wrecked. Warehouses 1 to 6 behind these structures were riddled by flying debris and their roofs and walls caved in from vertical and horizontal components of the concussion wave. Warehouse 1 was set afire and burned to the ground.

A small, two-story, waterfront cafe located just across the road from the end of the North Slip lay in direct line of the blast and was destroyed utterly. To the west behind this structure the Molasses Company office, a frame building, was entirely destroyed and three metal tanks were badly collapsed and bent.

A number of box cars present within a radius of 1,000 to 1,500 feet from the Grandcamp showed depressed roofs and caved-in sides; several caught fire from incandescent missiles.

Petroleum installations in the explosion area

* From the Departments of Medicine and Surgery, University of Texas Medical Branch, Galveston, Texas.

were damaged partly by concussion but chiefly by missiles, some of which were responsible for tank fires. A large spheroid at the Richardson Oil Plant, although empty except for a residue of hydrocarbon gases, exploded a few seconds after the ship and may have been responsible loading at Pier A while the turbine drive was undergoing repairs, had broken loose from its mooring lines at the time of the Grandcamp explosion and drifted across the slip where it came to rest against the Wilson B. Keene, a converted Liberty ship, with one anchor down.

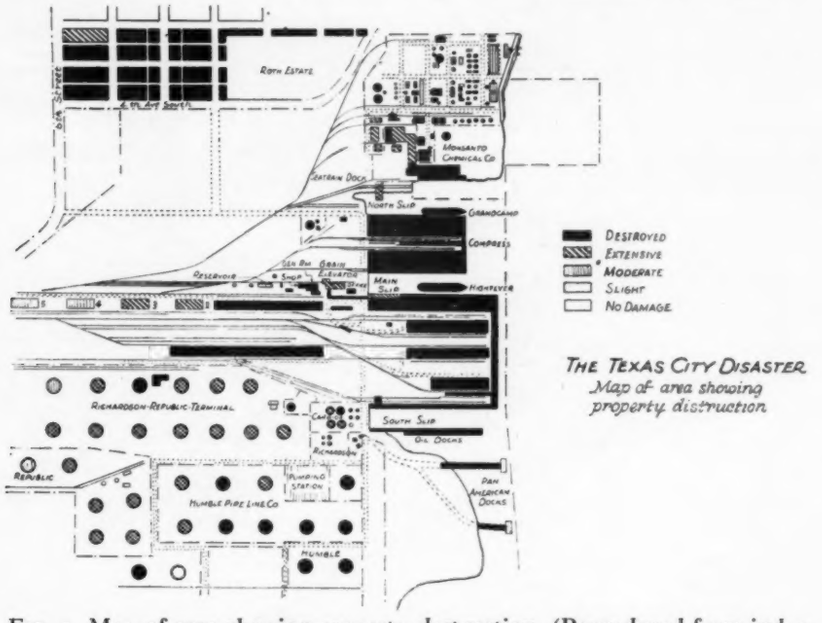

FIG. 1. Map of area showing property destruction. (Reproduced from industrial report of George Armistead, Jr. The Ship Explosions at Texas City, Texas, on April 16 and 17, 1947 and Their Results.)

for the second blast heard and felt by many persons who erroneously attributed it to an explosion in the Monsanto plant proper.

Heavy destruction of residential property resulted in the region to the northwest of the dock area. Several large buildings on the principal business street, approximately 5,000 feet away, collapsed as the walls and roof caved in. Practically all glass windows in the entire community were blown out. Fortunately no fires occurred outside the industrial sections.

THE SECOND EXPLOSION

Because of the heavy population of the area at the time of the first explosion, all efforts were immediately concentrated on rescue work; and, as little attention could be given to fire-fighting during the first few hours, a great deal of damage ensued which might have been avoided under less catastrophic circumstances. By the end of the day, however, most of the fires outside the Monsanto plant were under control and it was not until about dusk that fires were reported on board the High Flyer. This ship, a C-2 cargo vessel which had been In addition to 2,000 tons of bulk sulfur and a quantity of knocked-down box cars the cargo of the High Flyer contained 961 tons of ammonium nitrate fertilizer. Active fire-fighting was begun and an attempt was made about 11:00 P.M. to tow the ship out to sea by means of tug boats with volunteer crews. Although the anchor chain was cut, efforts at dislodging the High Flyer from the Wilson B. Keene were not successful and were abandoned. Soon after 1:00 A.M. fire-fighters noticed that smoke coming from the burning ship showed the same peculiar orange color that had been apparent shortly before the Grandcamp blew up and warning was passed along to all workers to leave the area as quickly as possible. Hence, the second explosion, which occurred at 1:10 A.M. on April 17th, was responsible for relatively few casualties. The blast equalled the earlier one in force and intensity in spite of the fact that the High Flyer contained less than half as much ammonium nitrate as the Grandcamp. It is believed, therefore, that probably only half of the chemical on the Grandcamp, that contained in the Number Four hold only,

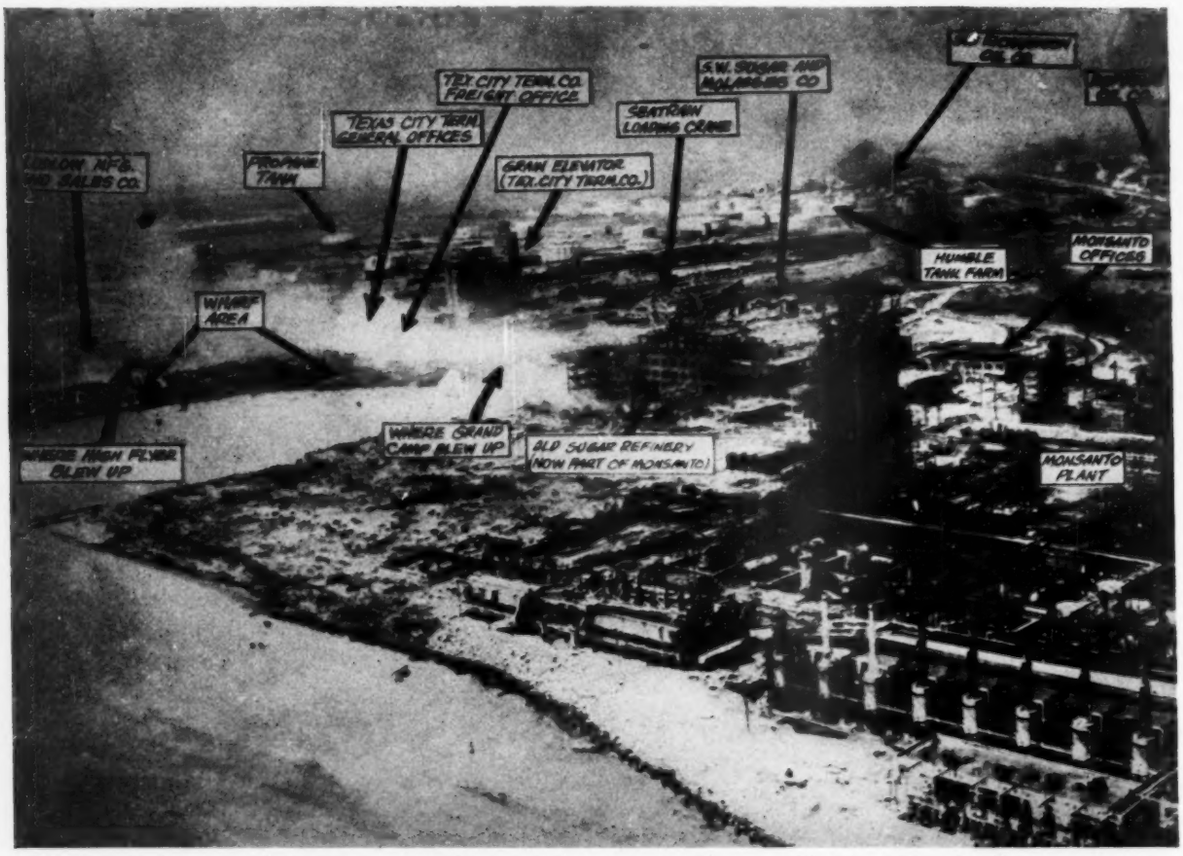
TEX. CITY TERM. CO. FREIGHT OFFICE
TEXAS CITY TERM. GENERAL OFFICES
S.W. SUGAR AND MOLASSES CO.
SEATRAIN LOADING CRANE
GRAIN ELEVATOR (TEX. CITY TERM. CO.)
HUMBLE TANK FARM
MONSANTO OFFICES
WHARF AREA
WHERE GRAND CAMP BLEW UP
OLD SUGAR REFINERY (NOW PART OF MONSANTO)
MONSANTO PLANT

FIG. 2. Aerial view of disaster area made several days after explosions. (Houston Press Staff photograph.)

where the fire originated, was detonated in the first explosion which otherwise might have been of even greater severity and of more disastrous consequence.

With the disintegration of the High Flyer and the aft end of the Wilson B. Keene, against which it had rested, a great, flaming-pink, mushroom-shaped cloud of smoke rose high into the air and incandescent missiles were scattered in all directions. Almost all of the remaining structures in the area with the exception of the grain elevator and the water tanks were wrecked and set afire. In addition a number of large petroleum tanks in the various refineries were fired by incandescent fragments. There was some spread of fire later in one field because of immediate lack of available equipment for proper control. It was estimated that approximately 22 per cent of tankage in the area, mostly crude oil, was damaged or lost. Dock fires resulted from puncture of pipe lines and oil spillage with consequent destruction of wharves, pipeline supports, box cars and other wooden structures. These fires were extinguished for the most part within twenty-four hours. Fires continued at the Monsanto plant for another day and there was still smouldering among the warehouse ruins almost a week after the disaster. (Fig. 2.)

In an industrial survey of property damage a careful study was made of the distribution of wreckage from the structural parts of the Grandcamp and High Flyer and remnants of their cargoes. In size the fragments ranged from a few ounces to several tons and their location showed the effect of widely varying force and velocity. Within 500 feet there was scarcely a square foot which was not covered with debris; many pieces weighed from 1 to 5 tons. At 1,500 feet, missiles were scattered about 5 feet apart and averaged perhaps 20 pounds with occasional 1 or 2 ton masses of steel plate. One huge fragment weighing 20 tons traveled 2,500 feet to a point where average particles weighed only a few pounds. Beyond this distance scattering of missiles was considerably less uniform and more haphazard. However, there were a number of very large fragments, 1 or 2 tons being reported at 4,500 feet from the center of the blast. Identifiable portions of

the cargo of the Grandcamp were picked up 10,000 feet from the dock area.

The detailed mechanism which caused the detonation of ammonium nitrate by fire is still unknown and attempts to produce explosive effects by experimental means have not been successful. Nevertheless, ammonium nitrate explosions and fires have occurred in the past with considerable property damage and loss of life as a result in some instances. A number of such accidents have been reported in the literature by Dr. C. E. Munroe (*Chem. Met.*, 26: 537, 1922) and R. O. E. Davis (Circular No. 718, U. S. Dept. of Agriculture, March, 1945.) George Armistead, Jr., who prepared an industrial report of the Texas City Disaster (The Ship Explosions at Texas City, Texas, on April 16 and 17, 1947 and Their Results), cites from an independent review of the literature thirteen ammonium nitrate catastrophes in this country and Europe in the past thirty-one years and a previous fourteenth accidental explosion produced in an English dentist's laboratory in 1896. The most serious explosion prior to the Texas City disaster took place at Oppau, Germany, in 1921, at which time more than 500 persons were killed following blasting of caked ammonium nitrate fertilizer by dynamite in order to facilitate handling of the material.

STATISTICS

An accurate count of casualties in the Texas City Disaster has been impossible to obtain in spite of the best efforts of all workers. Many persons received first aid only and as the town was almost completely evacuated for several days until danger of continued explosions was considered unlikely, there was considerable dispersion of minor casualties over a wide area. The Red Cross and Galveston County Public Health Nursing Service looked after most of the indigent population and the several thousand members of laborers' families whose homes had been destroyed by the blast. But over a period of several months there arose among this group numerous medical problems which were not associated with the disaster, namely, acute infectious diseases and obstetrical cases, so that their records show some names of persons who were perhaps not in the area or who were not injured on April 16th or 17th. All lists of personnel involved showed inevitable duplication of names from spelling variations, particularly in the case of Latin-American workers. Hospital records were begun as quickly as possible by volunteer personnel but many patients were discharged after minor surgery without adequate reports being made. As there was a great deal of shifting about of patients from one institution to another during the first few days, even dependable hospital statistics are not available. Complete check on industrial personnel was hampered by the loss of official records by fire in many cases and by the fact that several companies employed transient day laborers as longshoremen and in other capacities. It is possible that some of these persons, officially listed as missing, were unharmed and simply left town to find other jobs without giving formal notification to any agency. Finally, the spectacle of the fire had attracted a great many sight-seers to the dock area, both on foot and in automobiles from neighboring communities. On these persons no comprehensive count could be made nor could an exact estimate be obtained of the number of men who had driven to the waterfront region to conduct business in person as a result of a general telephone strike which happened to be in effect at the time.

In round numbers there were about 560 persons killed or missing, 800 patients hospitalized and between 3,000 and 4,000 others with less serious injuries. This study is a survey of 3,000 casualties who were within 4,000 feet of the explosion center. In three-fourths of the cases it has been possible to discover the location of individual persons at the time of the explosion. Information has been obtained from the Red Cross, The Bureau of Identification of the Department of Public Safety, hospital and clinic records, personal communication with the various industrial agencies in the disaster area, a review of records of the Texas City Terminal Railway Company and the Monsanto Chemical Company, direct interview with a large number of patients and, finally, from questionnaires distributed to homeless "refugees" quartered at Camp Wallace by the Red Cross and to other persons willing and able to give a coherent account of their experiences.

According to available records there were no survivors among fire-fighters or crewmen who were either on the Grandcamp or standing alongside; no bodies were recovered among this group. (Fig. 3.) One employee of the Texas City Railway Terminal Company who stood on the dock approximately 30 feet from the

ship reported that he first fell into the water as the wharf disintegrated and then was blown 300 feet into the air over Warehouse O onto the tracks on the other side where he landed on his feet. He sustained no loss of consciousness and his injuries consisted of a crushing injury of one foot (which required amputation), perforation of both ear drums and mild head injury. His clothes were all blown off but he had no abrasions or lacerations. His survival must be considered something in the nature of a freak accident since no trace was found of the men with whom he had been standing at the time of the blast.

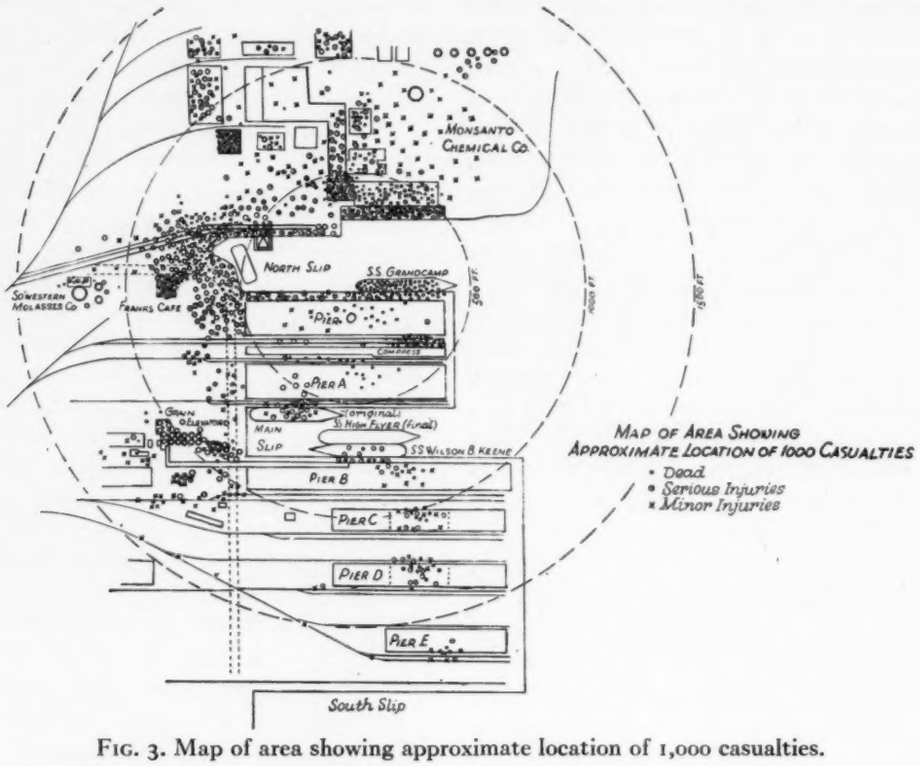

FIG. 3. Map of area showing approximate location of 1,000 casualties.

A colored laborer, standing in the back of a pick-up truck facing north about 50 feet from the ship, was blown horizontally about 500 feet into the open area at the end of the slip. He was momentarily unconscious but had no more serious injuries than fracture of one femur, an avulsion wound over the tendoachilles and perforation of the right ear drum. A total of nine hospitalized casualties reported that they had been watching the fire-fighting from the wharf within a distance of 100 feet from the ship. All of them showed evidence of mild or severe internal blast injury. It must be surmised that their escape from death was due to the fact that they were untouched by larger missiles in the barrage of flying debris. Almost all of the persons killed or seriously injured in the explosion were within a radius of 1,000 feet from the center of the blast. Less than fifty deaths occurred among patients admitted to hospitals. The majority were killed instantly by combined effects of blast, dismemberment by flying debris, injury from collapsing buildings, fire or drowning. The "tidal wave" reached the two most heavily populated areas, the open space at the end of the slip and the dock of the Monsanto warehouse. Fatal burns occurred chiefly in the Monsanto plant proper. In all probability most of these casualties were primarily from direct and secondary effects of the explosion. Rescue of bodies was impossible during the height of the fire in the chemical plant and identification of remains was impossible in some cases. In others it was achieved by recognition of keys and other metallic articles found with ashes. It is significant to note that of the patients surveyed there were no deaths which could be attributed to fire and only seven patients with severe burns of any type. Medical problems associated with the Texas City disaster thus differed greatly from those in such catastrophes as the Cocoanut Grove Fire.

In the immediate area back of the docks

there were in an open field approximately twenty goats, seven or eight cows, several sheep and a mule. As far as could be determined none of these animals were injured in any way except the mule which was killed by a large steel missile.

DISPLACEMENT OF PERSONS

A study of displacement of personnel involved in the explosion furnishes interesting proof of the direction of the various blast force components together with the haphazard and unpredictable effects which they produced. Of 461 persons questioned, 27 had no displacement; 256 were knocked down either from concussion or being struck by debris, or both; 86 reported that they were blown horizontally backward for distances which varied from a few feet to several hundred in a few instances. Forty-five were caught by the suction wave and blown horizontally forward in the direction of the blast. Eleven persons were blown vertically in the air for some distance and landed in their approximate former positions. Four were displaced first vertically and then horizontally backward; three first vertically and then horizontally forward; two vertically and laterally; five showed only lateral displacement; two lateral and forward movement.

Of nineteen workmen on ladders and tanks in the industrial area, fourteen were blown to the ground with considerable force and five were blown down and then horizontally backward. The greatest displacement occurred in those persons close to the center of the blast and in those at more remote distances who happened to be within direct line of the blast without intervening protecting buildings.

INDIVIDUAL IMPRESSIONS

First-hand descriptions of events showed the variations which might be expected. There was fairly uniform opinion that a peculiar orange-colored smoke was seen shortly before the ship exploded but considerable disagreement as to the number of blasts, whether one, two or even three. It was believed by many that the boat exploded in sections and two distinct blasts a few seconds apart were heard and felt in Galveston, several miles away across the bay. The industrial survey gave evidence, as has been mentioned, that the second blast was due to the setting off of a spheroid at one of the oil plants. Nevertheless, a number of persons reported that they were covered by debris in the first explosion, uncovered in the second; or that they were blown first in one direction and after getting up were knocked down by another blast. Two women reported that they ran from their homes three or more blocks away to the waterfront area on hearing the first blast and were just in time to be struck by debris at the time of the "second explosion."

Persons at some distance from the explosion center experienced sensations similar to those produced by earthquakes, that is, rumbling underfoot or shaking of buildings with accompanying rattling of dishes and furnishings. Those in the immediate area, however, described most vividly the effects of the air blast. An engineer walking away from the docks near Warehouse A was immediately aware of "a soft powerful force" against his body a fraction of a second before he was knocked down and surrounded by a thick black vapor with soft heavy particles falling on his face and body. Others spoke of a "rush of wind." Only a few of the 112 known survivors who were within 500 feet of the Grandcamp remembered hearing the explosion and many within 1,000 feet had no recollection of hearing any sound at all. Among the group of patients who were unconscious for varying periods of time it was noted that the majority recalled feeling the air blast before blacking out even though they sustained moderately severe head injury from flying debris or "blast concussion."

Many workmen and spectators in the area, even inside buildings, had most or all of their clothing blown off by the blast. One colored laborer, unfortunate enough to be caught in the privy back of the waterfront cafe at the precise moment of the explosion, reported "Ah got all mah clothes blowed off but mah underwear and mah shoes, thank de Lawd!" It was surprising that a number of workers whose clothes were literally torn off escaped with only a few scratches and had no demonstrable internal blast injury. Dr. Stafford Warren in personal communication has suggested that this phenomenon might be due to rolling or whirling waves of low pressure produced by friction at the foot of the blast wave as it traveled along the ground.

The "thick black vapor" previously described which filled the waterfront area and rose as a large cloud above Texas City contained huge particles of soot and droplets of

FIG. 4. View showing multiple lacerations of trunk. Case 1.

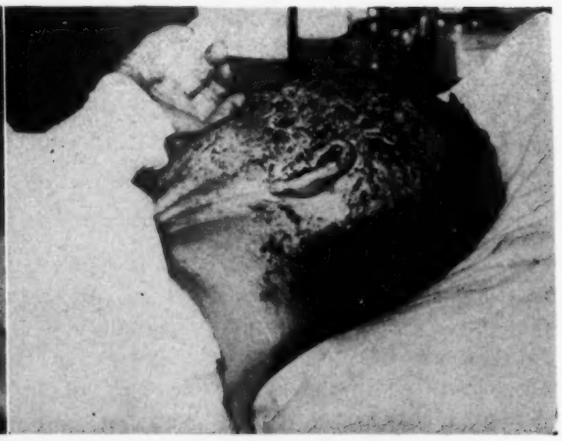

FIG. 5. Lateral view of head. Case 1.

oil and heavy chemicals. Persons unprotected by buildings had their clothing saturated and were so uniformly covered with the heavy, tarry substance that on admission to hospitals white and negro patients in many instances were indistinguishable. The smoke contained vapors, also, which were extremely irritating to the conjunctival and respiratory mucous membranes although the symptoms produced were only transient in character.

To those disaster victims in the open area at the end of the slip on the Monsanto warehouse dock and as far back as the Molasses Company office where the water rose to a depth of about 4 feet, the so-called tidal wave was perhaps the most frightening experience of all. Members of families or friends standing together to watch the fire were separated by the rush of water; disorientation and confusion added to shock and injury. Many were able to swim to land or cling to floating timbers until the water receded but, undoubtedly, numerous deaths were due primarily to drowning in the case of children and those stunned by debris or the effect of the blast.

GENERAL PATTERN OF INJURY

Among the 800 persons admitted for hospitalization certain common features were noted. Most prominent were as follows: first, the multiplicity of lesions in the individual patient; second, the characteristic finding of numerous punctate lacerations, usually from imbedded glass particles and concentrated on the head and extremities; and third, the frequency of fractures of all types. Conspicuously absent were patients with massive avulsion wounds and with severe burns who did not survive their initial injuries. The majority of patients were in a state of mild shock and responded readily to one or two units of plasma. More than one-third had perforation of one or both ear drums or presented symptoms other than deafness which were indicative of primary blast lesions. The following case histories with accompanying photographs will serve to illustrate typical lesions in the more seriously injured.

CASE REPORTS

CASE I. W. C. H., a white male, aged twenty-nine, was approximately 500 feet from the Grandcamp in the Monsanto storeroom. He was standing with his left side toward the ship and it was reported that he was blown about 10 feet laterally. He did not hear or feel the blast and was unconscious for about thirty-six hours afterward. He was injured by flying glass and by debris from the building as it collapsed. Injuries sustained were (1) multiple lacerations of the left face, scalp, trunk and extremities with embedded glass fragments covering the entire left side; (2) perforating wound of the left chest posteriorly with mild lung injury; (3) fracture of the left scapula (glenoid cavity); (4) foreign body, left orbit; (5) head injury, moderately severe. (Figs. 4 and 5.)

CASE II. R. B., a colored male, aged forty-five, was standing just outside Warehouse O at the time of the explosion with his back toward the ship. He did not hear or feel the blast. He was knocked down and whirled around and was unconscious for a few moments. He was covered by water but managed to wade out without assistance. He complained of blurring of vision, deafness, abdominal and chest pain, headaches and dizziness. His injuries were (1) perforation of both ear drums; (2) contusion of right kidney; (3) acute gastric dilatation (second-

FIG. 6. X-ray of chest showing blast injury of left lung. Case II.

FIG. 7. View of face showing compound fracture of mandible. Case III.

ary); (4) atelectasis and intrapulmonary hemorrhage of left lung; (5) mild concussion; (6) multiple minor lacerations; (7) loss of several teeth; and (8) corneal blast injury? (Fig. 6.)

CASE III. H. B., a white male, aged thirty-six, was walking away from the polystyrene building toward the Monsanto gate at the time of the explosion. He did not hear the blast but felt a rush of wind which knocked him down. He was unconscious and disorientated for about forty-eight hours. In spite of the severity of his injuries he had no complaints suggesting lung or abdominal blast injury. Injuries sustained were (1) fracture of the mandible; (2) penetrating wounds of the mouth; (3) fracture of the skull; (4) perforation of both ear drums; (5) compound fracture of the right radius; (6) intracranial injury, moderately severe; and (7) multiple minor lacerations. (Fig. 7.)

CASE IV. W. P., a white male, aged thirty-six, was working as an engineer in the main office building at Monsanto. When the accident occurred, he was sitting at a desk with his right side turned toward a window a few feet away through which he had been watching the burning ship. He heard and felt the blast which blew him upward out of his chair and backward under a table. He was completely "blinded" by flying glass and was dazed but not unconscious. In addition to other injuries he complained of chest pain and coughed up blood intermittently for a week. His injuries were (1) penetrating wound of the right eye with prolapse requiring evisceration; (2) multiple lacerations of the right side of the face with severance of facial nerve and parotid duct; (3) lacerations of neck, eyelids, left deltoid region and both lower extremities; (4) perforation of right ear drum; and (5) blast injury of lung. (Fig. 8.)

CASE V. N. B., a colored female, aged thirty-seven, was standing out in the open near the Seatrain with her left side turned toward the ship. She felt the blast and saw debris flying through the air in all directions before she was knocked unconscious by a flying missile. When she "came to," she was in water up to her waist and part of her clothes had been blown off. The patient was approximately two months pregnant at the time, and within an hour had an inevitable abortion without complication. Injuries sustained were (1) severe laceration of the left leg; (2) lacerations of the scalp; (3) mild head injury; (4) perforation of the left ear drum; (5) spontaneous abortion; and (6) minor abrasions and contusions. (Fig. 9.)

CASE VI. A. N. D., a white male, aged twenty-one, had just come off fire-fighting duty on the French boat and was standing at the end of the docks facing the burning ship. He was blown a considerable distance backward into the water which flooded the area. He did not lose consciousness for several minutes but was comatose thereafter for forty-eight hours. Convalescence was complicated by urinary infection, a severe infection of the right leg and serum sickness. His injuries

FIG. 8. View showing multiple face lacerations. Case IV.

were (1) basal skull fracture; (2) severe intracranial injury; (3) compound fracture of the mandible; (4) compound fracture of the right tibia; (5) compound fracture of the left tibia and fibula; and (6) urinary retention. (Fig. 10.)

CASE VII. S. R., a colored male, aged thirty-nine, had just come from loading flour on the High Flyer and was standing at the end of Pier O facing the burning ship. When the explosion occurred, he was thrown upward so high that he could see over Warehouse O; he was then blown laterally into the water near the Seatrain installation. He did not lose consciousness and was able to swim to land. Most of his clothes were blown off. Injuries sustained were (1) perforation of both ear drums; (2) severe scalp lacerations; (3) severe laceration of left upper arm with extensive infection; (4) left ulnar paralysis; and (5) laceration of right foot. (Fig. 11.)

Figure 12 shows in graphic form a comparison of the different types of injuries in the entire series of patients studied. Minor lacerations and contusions occurred in a total of 1,452 persons as compared with 332 with major lacerations and 331 with one or more fractures. Head injuries were considered severe in 56 cases and mild in 161 others; these included for the most part the 186 patients who reported a period of unconsciousness ranging from a few

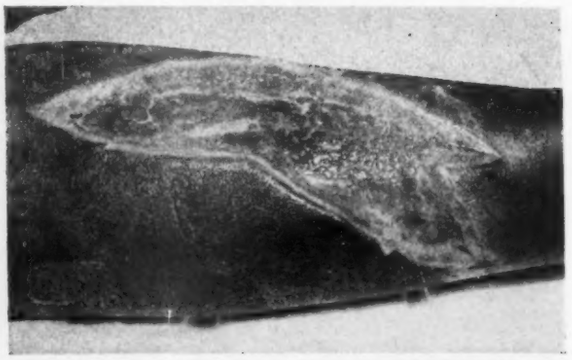

FIG. 9. View showing avulsion wound of left leg. Case V.

seconds to 48 hours. There were 38 severe eye injuries (one patient required evisceration of both eyes); 85 were of milder degree. Five patients reported blurring of vision for several hours but adequate studies were not made to determine whether or not they suffered corneal blast injury. Only 7 serious burns were discovered; the 44 cases of mild burns were for the most part sustained from hot water heaters and stoves rather than from fires set off by incendiary missiles from the Grandcamp. Of interest but not recorded on the chart were eleven cases of delayed or missed menstrual periods and two abortions in women who were within 1,000 feet of the explosion center. A number of other pregnant patients in zones further removed reported no complications.

Perforation of ear drums has been considered as the only single objective sign in the study of pure blast injury. Although most cases were found within a 1,000 foot radius of the Grandcamp, many perforations occurred in persons outside of this area without protection of buildings in the residential zones (2,000 to 4,000 feet), and one case was found almost a mile away in the most distant region covered by the survey. A total of 274 patients with perforation were enumerated, 140 with both drums affected and 134 with only one. Hyperemia of the drum with deafness lasting several days was reported in twelve instances.

Undoubtedly figures for perforation fall short of the actual number which must have occurred. Surprisingly enough, a few patients quite close to the blast center had no ear drum injury. One Terminal Railway official who went virtually unscathed through both explosions in spite of being about 600 or 700 feet from the blast center on each occasion, thought that his ear drums were protected by the fact that he was

FIG. 10. X-ray showing compound fracture of both legs. Case VI.

FIG. 11. View showing lacerations of left arm before skin grafting. Case VII.

yelling with his mouth wide open at the moment each ship blew up. It was generally true that within the first zone persons standing with one side toward the blast lost only the ear drum on that side, whereas those further back in the second zone were likely to have perforation of both drums in spite of their position. Patients who were protected from the direct effects of the concussion wave either within buildings or by intervening structures showed as a rule only a small perforation. Many who stood outside in direct line of the ship lost the entire drum on one or both sides.

Evidence of blast injury to the lungs was unfortunately not substantiated by x-ray examination in the majority of cases since early attention was of necessity given to diagnosis of fractures and other conditions amenable to surgical treatment. A total of 155 patients reported either severe pain and tightness in the chest accompanied by shortness of breath or coughing up of blood either on one occasion or for as long as a week. In the absence of fractured ribs or severe chest injury it seems that these symptoms must be presumptive evidence of blast injury to the lungs.

In seventy-four patients within the immediate blast area there were gastrointestinal symptoms, namely, abdominal pain, nausea, vomiting, vomiting of blood or melena. Eight patients had severe injury to the kidneys and bladder; twenty-six others, some of whom were not hospitalized, complained of urinary retention which is a fairly common symptom of blast injury. No attempt has been made to tabulate the number of patients with persistent cerebral symptoms since it is difficult to differentiate psychic and organic factors without thorough study. A great many patients with so-called blast concussion showed no signs of cerebral injury at the time of hospitalization; on the other hand, the majority of those who survived serious head injuries have made most satisfactory recoveries.

In reviewing the orthopedic injuries it has been impossible to secure accurate figures on the number of compound fractures except at the John Sealy Hospital where there were 34 in 133 separate fractures (including those of the skull). It will be noted that fractures of the upper and lower extremity were about equal in number with a large number of rib and skull fractures and eleven instances of fracture of the scapula which gives an indication of the severity of injury in many cases.

TYPES OF INJURY ACCORDING TO ZONES

Three-fourths of the entire group of patients requiring hospitalization were within a radius of 1,000 feet from the explosion center. There were 112 survivors within 500 feet and 418 in the area from 500 to 1,000 feet. Within this area where families of workmen in the industrial region at the dock had their homes. Here typical injuries were minor lacerations, contusions and abrasions sustained indoors. Surprisingly enough, a great many persons reported forward displacement in this zone, a number

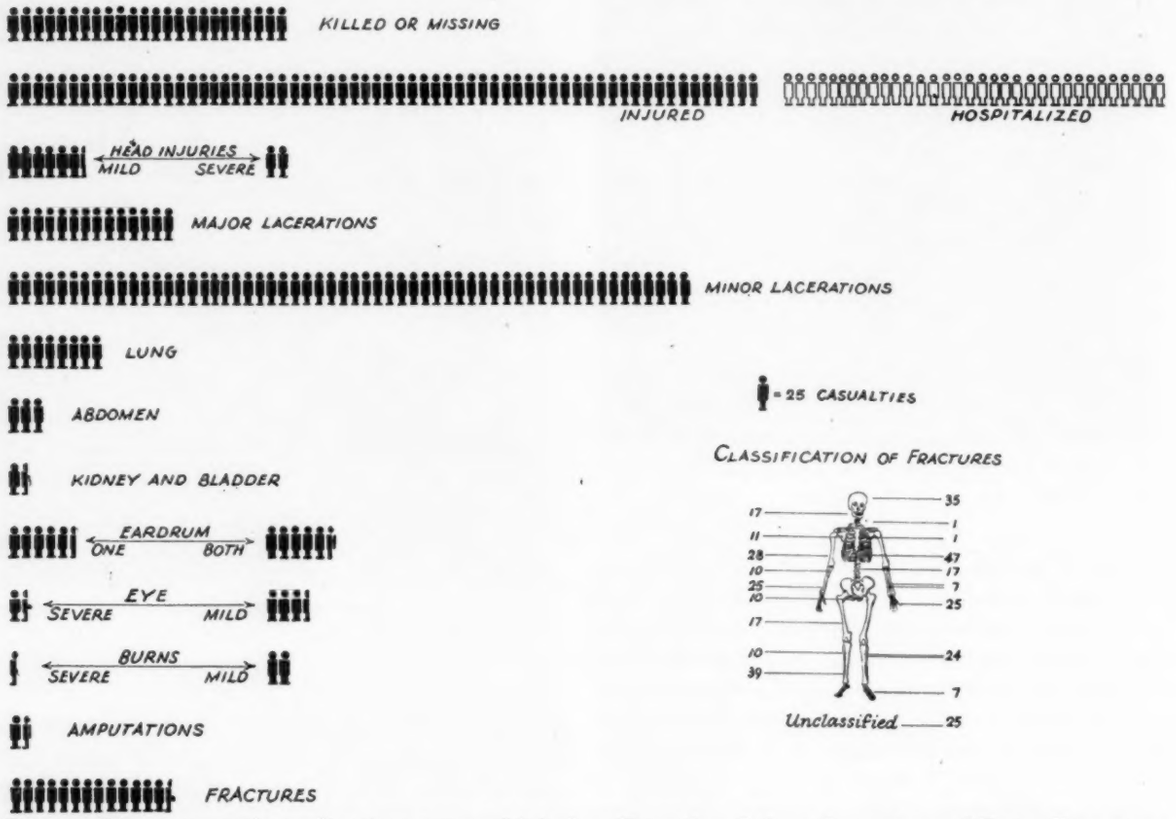

FIG. 12. Shows comparison of various types of injuries. (Reproduced through courtesy of Texas Reports on Biology and Medicine from article by Blocker.)

first zone there were also approximately 250 persons who escaped with no demonstrable injuries. As a general rule those who were out in the open exposed to the barrage of missiles suffered more severe injuries than those inside the buildings which collapsed and they sustained considerably greater damage from effects of the blast itself.

In the second zone (1,000 to 2,000 feet) major injuries were found almost entirely in persons within buildings which disintegrated from the force of the concussion. A fair number of these had perforation of ear drums or symptoms suggesting internal blast injury. An occasional casualty resulted from scattered missiles of steel or other metal.

The third zone (2,000 to 3,000 feet) was heavily populated with approximately 1,400 school children in addition to a large residential being blown out of doors in the direction of the explosion center. Those who were in direct line of the blast, chiefly in the blocks just northwest of the open space of pasture land behind the Monsanto plant, had the usual signs of blast injury.

Beyond the third zone very little displacement of persons occurred and only an occasional patient reported ear drum perforation.

In the fourth zone (3,000 to 4,000 feet) and beyond casualties showed for the most part only minor injuries, chiefly lacerations from flying glass particles. (Fig. 13.)

Injuries in the High Flyer Explosion. As mentioned previously, by the time of the second explosion on April 17th shortly after midnight, most of Texas City had been evacuated and the waterfront area had been cleared except for about thirty fire-fighters and rescue workers.

Furthermore, since warning was given of impending danger, according to the best information available, there was no one within 500 feet of the explosion center. Only one person was reported killed. Seven were hospitalized for serious injuries from falling debris. The remainder escaped with minor lacerations, abrasions, perforation of ear drums, etc.

HOSPITAL DEATHS

Of the official list of 563 persons killed or known definitely to be missing following the Texas City explosions, only fifty died following hospitalization. At the John Sealy Hospital there were eighteen deaths. Four patients were dead on admission. The remaining fourteen may be summarized as follows:

I. Death twenty-four hours after injury, April 16th and 17th	
Head injury	3
Head injury plus compound fracture or traumatic amputation	2
Head injury and crushing wound of chest	2
Ruptured spleen and head injury	1
Penetrating abdominal wounds, severe shock, gas gangrene and anesthesia (death on operating table)	1
II. Death two to five days after injury, April 18th to 23rd	
Head injuries	2
Head injury, compound fracture, abdominourinary fistula, uremia	1
Transverse myelitis, head injury, multiple internal blast injuries	1
III. Death one month after injury	
Massive pulmonary infarcts	1

It was unfortunate that only a few autopsies were performed on patients who died in hospitals and that none were made on the large number of victims brought to the public morgue. Cause of death in many instances was obviously due to dismemberment from flying particles of steel and other debris. In others it was impossible to tell without adequate postmortem examination whether death was due primarily to the effects of the blast, to drowning, fire, head injury or to a combination of several of these. Autopsies on hospital patients showed in addition to individual injuries and complications typical signs of blast injury, namely, scattered petechiae, small hemorrhages and hyperemia in sections of the brain, heart, lungs, liver, kidneys and gastrointestinal tract. One patient who died forty-eight hours after injury showed acute fatty metamorphosis of the liver and another on the same day had a considerable amount of diffuse fatty change in this organ.

PLAN OF OPERATIONS FOR TREATMENT OF DISASTER VICTIMS

With a catastrophe of such magnitude and in view of imminent danger of further explosions it was only proper that first attention be given to rescue work and to the transportation of injured persons from the immediate disaster scene. First call was for medical and nursing personnel, litters and litter-bearers, ambulances, blankets (for persons whose clothing had been blown off), morphine, plasma and emergency bandages. All first-aid equipment in the industrial plants had been destroyed or contaminated but within a remarkably short time many volunteer workers and a large supply of equipment had been rushed to the area. Chief shortage in equipment was probably of temporary splints for patients with obvious or suspected fractures. Since the only hospital beds available in Texas City were in small, private clinics, it was necessary to transport patients to larger hospitals. About two-thirds of the seriously injured persons were brought to Galveston, the remainder being taken to Houston and to neighboring towns. Three large hospitals in Galveston were immediately alerted for treatment of disaster victims, namely, St. Mary's Infirmary, the county Hospital, the United States Marine Hospital and John Sealy Hospital, the teaching institution of the University of Texas School of Medicine where classes were dismissed and all staff members and medical students reported for duty. In the short interval between news of the disaster and the arrival of the first patients at the John Sealy Hospital a Chief of Operations was appointed to serve with the Superintendent of the Hospital and temporary plans were formulated for the handling of casualties. At the same time all patients who could possibly be dismissed were sent home; others were moved so that entire wards were available for treatment of the injured. Calls were put out through the Red Cross for beds, linen and blankets, blood, penicillin, surgical supplies and nurses. The Commanding General of the Fourth Army sent a Medical Batallion to staff nearby Ft. Crockett and a committee of five to expedite Red Cross requests. Almost immediately hundreds of offers of help began to pour in and it was necessary to make arrangements for answering

calls and telegrams and to designate disposition of supplies as they arrived.

All patients were brought first to the Out-Clinic Building and placed either on mattresses on the floor or in available wheel chairs. A cursory physical examination was made and a Station Hospital. Others were dismissed with advice to return to the Out-Patient Department for dressings or to their private physicians.

2. Critically injured patients with the exception of those taken immediately to the operating room were sent to shock wards to be made

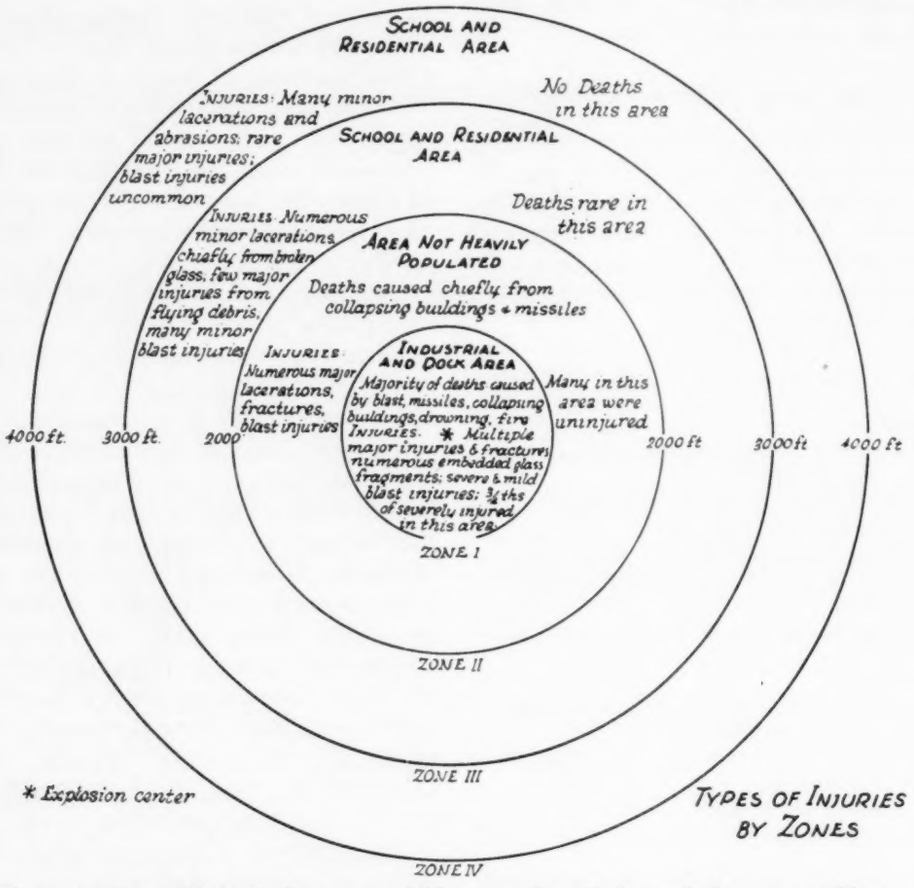
SCHOOL AND RESIDENTIAL AREA
No Deaths in this area
INJURIES: Many minor lacerations and abrasions; rare major injuries; blast injuries uncommon
SCHOOL AND RESIDENTIAL AREA
Deaths rare in this area
INJURIES: Numerous minor lacerations, chiefly from broken glass; few major injuries from flying debris; many minor blast injuries
AREA NOT HEAVILY POPULATED
Deaths caused chiefly from collapsing buildings & missiles
INJURIES: Numerous major lacerations, fractures, blast injuries
INDUSTRIAL AND DOCK AREA
Majority of deaths caused by blast, missiles, collapsing buildings, drowning, fire
Many in this area were uninjured
INJURIES: * Multiple major injuries & fractures; numerous embedded glass fragments; severe & mild blast injuries; ¾ths of severely injured in this area.
4000 ft.
3000 ft.
2000
2000 ft
3000 ft
4000 ft
ZONE I
ZONE II
ZONE III
ZONE IV
* Explosion center
TYPES OF INJURIES BY ZONES

FIG. 13. Types of injuries by zones within 4,000 feet of the explosion center. (Reproduced through courtesy of the Texas Reports on Biology and Medicine from article by Blocker.)

note pinned to each person indicating the name, blood pressure, pulse, list of injuries, amount of morphine and plasma given before admission and a statement of general condition. Plasma was started on all patients in shock except those few with severe hemorrhage who were sent immediately to surgery. The general procedure was as follows:

1. Patients without severe injury were sent to one of a number of minor surgery rooms for cleansing, débridement and suturing of wounds, for the administration of tetanus antitoxin and general examination for evidence of internal injury or overlooked fracture. Those who required further observation were evacuated to a Convalescent Unit set up at the Fort Crockett

ready for surgery. These patients received plasma, blood, intravenous fluids, tetanus antitoxin and penicillin. Oxygen was given as indicated and suitable analgesics were administered under the direction of the anesthesia staff. Following physical examination, patients were seen in consultation by various specialists and emergency laboratory work was taken care of.

3. Meanwhile, patients classified as seriously injured were sent to preoperative wards following cleansing of wounds, application of dressings and x-ray examinations. In the wards they received plasma, blood, intravenous fluids, tetanus antitoxin and penicillin. Specialists were available for consultation. Patients who required only closed reduction of fractures were

referred to cast rooms and then were sent on to postoperative wards.

Ten operating teams were employed at the John Sealy Hospital with three or four men on each, working in shifts for a period of forty-eight hours until all major surgery was completed. As a general rule, no attempt was made at primary closure of large and grossly contaminated wounds except on the face. A staff man was in charge of each operating room and there were three teams of volunteer surgeons. The medical anesthesia staff was in charge of all analgesics, anesthesia, oxygen and blood therapy. A great many calls came in from volunteer surgeons all over the state and country. It would have been necessary to bring in additional operators if casualties had included a large number of severely burned patients. However, for the needs at hand there were at the time approximately seventy-two veterans (formerly military officers) serving as resident doctors in various departments of the hospital and almost without exception these men had had active service overseas or were acquainted with the problems of handling a large number of critically injured patients. Postoperative wards were under the direction of the resident staff of General Surgery with Red Cross and volunteer nurses in addition to regular ward and student nurses. Each ward officer was given a team of medical students who were available for histories, physical examinations, routine laboratory work, dressings and administration of intravenous fluids, gas gangrene antitoxin and chemotherapy. They also served, when necessary, in the capacity of orderlies so that patients could be taken to and from x-ray with dispatch. Each ward was equipped with a messenger system so that the Chief of Operations could keep up at all times with calls for supplies and equipment from the individual units. All patients in the John Sealy Hospital were examined for eye and ear injuries by the Departments of Ophthalmology and Otolaryngology and other specialists were called in as required for treatment of the various complications of patients.

On the morning following the disaster wounds of every patient were inspected for possible complications of gas gangrene and an isolation ward and operating room were set up for débridement of all suspicious wounds. Massive doses of intravenous penicillin and x-ray therapy were employed in all cases with positive smears for gas-forming organisms.

MEDICAL AND SURGICAL COMPLICATIONS

At the John Sealy Hospital there were seven instances of clinical gas gangrene but no deaths could be attributed to the infection. Two patients who died within twenty-four hours after injury from severe head trauma and multiple penetrating abdominal wounds showed evidence of early gas gangrene; a third who died five days after the disaster from head injury and uremia following an abdomino-urinary fistula had evidence of beginning gangrene in the abdominal wall. Of the four patients with clinical gas gangrene symptoms, all made good recovery following vigorous therapy. Two patients had high thigh amputations, one had extensive débridement for a gangrenous lesion of the chest wall and one with gangrene of the upper arm was successfully treated without amputation.

Every patient who had a positive smear for gas-forming organisms received wide débridement of suspicious wounds, x-ray treatment of the area and massive doses of penicillin.

Secondary infection of surgical wounds was not a major problem but did develop in a limited number of cases. Amputation was required in one burn patient following a septic infarct in one of the leg vessels. In one patient amputation was required for dry gangrene resulting from laceration involving a main branch of the femoral artery. In two others with compound fractures amputation was performed following an overwhelming osteomyelitis process. One patient with diabetes had amputation following fracture of the left tibia and fibula with involvement of the knee joint.

Medical problems encountered were chiefly pulmonary. Seven patients had pneumohemothorax following penetrating chest wounds. Twenty had evidence of atelectasis and/or hemorrhage which appeared to be due to blast injury of the lungs. Two patients had closed pneumothorax. In three patients there were large pulmonary infarcts; one of the latter developed approximately a month following injury and was rapidly fatal. In another patient pulmonary embolism was followed by a bronchopleural fistula and massive effusion and infection; following eventual lobectomy, however, he made good recovery. There were four instances of postoperative pneumonia. A few

urinary complications occurred but there were apparently no ill effects following transient retention of urine in a number of cases. One burn patient developed toxic hepatitis as evidenced by jaundice and impairment of liver function. There were two patients with diabetes. One, as has been mentioned, required amputation following compound fracture; the other suffered only minor injuries.

In view of the large doses of tetanus antitoxin and gas gangrene antitoxin which were administered to the majority of the patients, it was anticipated that a large number of serum reactions might be encountered. In the isolation wards either benadryl or pyribenzamine were administered routinely for several days. These drugs were used with good effect on those in whom allergic skin reactions developed. Only a few patients had frank serum sickness; they had complete relief from symptoms following administration of 1,000 cc. of a solution of 0.1 per cent procaine in normal saline.

It was noted on preliminary examination of patients that the majority who were not in shock showed an elevation of blood pressure with the diastolic 95 or above. These cases have been studied and reported by Dr. Arthur Ruskin of the Department of Medicine.[1] There was one instance of paroxysmal tachycardia. One patient with multiple valvular murmurs was suspected of having congenital heart disease; on later examination all murmurs had disappeared and it was believed that signs had been due to toxic dilatation.

Among hospitalized patients at John Sealy only two or three acute psychotic disturbances arose which were thought to be precipitated by the disaster. A number of patients returned to the Out-Patient Department complaining of "concussion" headaches and dizziness. They were evaluated by both Neuro-psychiatric and Otolaryngology Departments and the majority cleared spontaneously within a few months' time. There were remarkably few patients who appeared with the so-called compensation neuroses. Most patients who attributed psychoneurotic complaints to the explosion were found to have been poorly adjusted individuals prior to the disaster.

PROBLEMS OF RECONSTRUCTION AND REHABILITATION

The problems of plastic surgery following the Texas City disaster were, in general, of rather minor nature. It was generally true that patients with severe avulsion wounds did not survive. With the almost negligible number of burn cases, acute problems were limited to lacerations of the face and treatment of mandibular fractures.

Plastic problems which arose during the convalescent and postconvalescent stages included chiefly covering of stumps, flaps and grafts for avulsion wounds of the extremities and revision of scars, particularly on the face. The General Surgical staff was confronted, following treatment of initial injuries, by a large number of patients requiring secondary closure of wounds. One patient was referred to chest surgery for lobectomy and there were a few who required either craniotomy or neuorrhaphy. Orthopedic problems in addition to infection were non-union and care and rehabilitation of patients with severe fractures. There was one instance of paraplegia involving both lower extremities. The Red Cross and Vocational Rehabilitation Agencies were most helpful in assuming responsibility for furnishing prosthetic appliances where indicated and for job retraining in amputation cases.

CONCLUSION

The Texas City disaster was the fifteenth of a series of explosions produced as the result of detonation of ammonium nitrate. At the present writing there must be added several additional catastrophes of similar nature and comparable intensity. It is beyond the scope of this paper to discuss the problems of prevention of such calamitous events. From experience in this area, however, and in view of the problematical danger of atomic bombing of large cities, it should certainly be recommended that a comprehensive civilian disaster program be formulated and made available to the entire medical profession for use in widespread emergencies.

A great many doctors, complacently unaware, perhaps, of disaster possibilities, may think that the American Red Cross "takes over" in the event of a major catastrophe. The Red Cross is admirably equipped to handle certain phases of relief and its services in the Texas City area cannot be overestimated. According to agreements with the American Medical Association, however, both organizations recognize that local physicians in a disaster region are primarily responsible for the care of the sick

and injured. It is the duty of the Red Cross to cooperate in supply necessary medical aid and in recruiting nurses and doctors where facilities are inadequate but the Red Cross does not presume to tell the doctor what to do or how to treat his patients.

Although it is desirable for medical disaster committees to be appointed in heavily industrialized communities where explosives and inflammable materials are manufactured or handled, it must be borne in mind that volunteer recruits solicited in advance are often not available in time of need for one reason or another. Furthermore, it is conceivable that a catastrophe may include among its victims all immediate medical personnel so that treatment of large numbers of injured persons may fall upon doctors who are unfamiliar with local conditions and unprepared for the tasks at hand.

A detailed disaster program for physicians should stress, first of all, a plan of organization of medical and hospital facilities to take care of patients efficiently and with dispatch. There is a general tendency for too many persons to be sent to the immediate disaster area with little or no equipment and with no designated authority in charge of first-aid activities. The direction of volunteer workers involves careful consideration if their efforts are to be put to effective use. The appointment of a clerical staff at the very outset of activities is of the utmost value in preventing confusion on every side. The names of victims and all material needed for purposes of record or reference should be arranged in orderly files on index cards and alphabetized for ease in handling. Many workers if left to their own devices will keep important information on small pieces of paper which are likely to be lost or misplaced. Others compile lengthy complicated lists in longhand which are unwieldy and are accessible to only one person at a time.

Proper certification of medical and nursing volunteer workers is extremely important if these persons are to perform duties for which they must assume medicolegal responsibility. Certain unscrupulous individuals are always at hand to exploit disaster victims for their own purposes and much embarrassment may be avoided if credentials are checked in advance. With rapid air transportation it is always possible to import well qualified surgeons and consultants to an area; only in a rare instance is an unskilled person justified in attempting a difficult operative procedure of emergency nature.

Adequate provision should be made for dealing with the press so that official information comes only from reliable authority. Following the Texas City explosions there were, for example, widespread and fantastic rumors concerning the danger of gas gangrene which was popularly believed to be the result of poison gases and of a highly contagious nature; actually the problem of gas gangrene was a very minor one and a great deal of needless panic might have been avoided.

A disaster program for doctors should include standard methods of treatment of burns and of all types of wounds as well as major medical complications and the use of plasma, blood and antibiotics. It must be emphasized that primary closure of large, heavily contaminated lacerations, no matter how tempting, is ill-advised and potentially a dangerous procedure.

Without a doubt the fact that hospital personnel had had military training and experience in World War II in handling large numbers of casualties was of prime importance in establishing and carrying through an organized plan of treatment of the more seriously injured patients in the Texas City Disaster. To the Army must go credit also for its assistance to the Red Cross in furnishing immediate personnel and supplies of every description from its various stores. Services of all individual physicians in the area were donated without charge for the period from April 16, 1947 to July 1, 1947, and all medical fees collected from insurance companies, the Red Cross and patients themselves were placed in general funds to be allocated either for research projects or for charitable causes. It was generally believed that the victims of the Texas City disaster were handled on the whole with admirable efficiency by local, Army and Red Cross workers with the entire situation a matter of group responsibility.

REFERENCE

1. Ruskin, Arthur. Blast hypertension. *Am. J. Med.*, 4: 228, 1948.

DISCUSSION

Edgar L. Gilcreest (San Francisco, Calif.): I should like to ask Dr. Blocker if he would tell us what he would do that he had not done that day, if they had another catastrophe like the one described. (Dr. Blocker answered by reading the concluding paragraphs from his paper which were omitted for lack of time.)

MARJOLIN'S ULCER*

A PREVENTABLE THREAT TO FUNCTION AND LIFE

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THE occurrence of malignant ulcers in cutaneous scars was described by Marjolin in 1828.[1] The scars which produce Marjolin's ulcers are always of long duration and subject to the more or less continuous trauma of tension, friction or weight-bearing. The sources of the scars are varied but burns rank high as a causative agent. While the cutaneous carcinoma which occurs in irradiated cicatrices or in the scars resulting from irradiation is not ordinarily classified as Marjolin's ulcer, the mechanism of production is not far different. Both depend upon the sequence of repeated ulceration and healing in a dense, relatively avascular, collaginous cicatrix covered by thin, unstable epidermis. The scar becomes progressively less vascular until an indolent ulcer appears which never completely epithelizes. In irradiated scars the element of perivascular infiltration which seems to be characteristic of these lesions adds to the ischemia and probably accounts for the more rapid progression of ulceration in such lesions than in those due to other types of trauma.

The duration of the scars before malignant ulceration develops is variable, occurring in from a few years to over half a century. The true Marjolin's ulcer is almost always a squamous cell carcinoma while the carcinoma in an irradiated scar may be either basal or squamous cell. It is impossible to determine the presence of malignant change except by microscopic section. Careful examination of the entire circumference of the ulcer may be necessary to find one small area of squamous cell carcinoma. Gross evidence of induration and irregularity at the margins of the ulcer and a deep necrotic base are suggestive of malignancy but are not conclusive. Regional lymph nodes are rarely involved early. Untreated carcinoma in a scar eventually causes death of the patient but remote metastases are slow to appear. In one of the author's cases which terminated fatally only regional lymph node metastases were found at autopsy. The slow progress of the neoplasm renders it susceptible of cure with radical surgical excision and skin graft plus local lymph node resection when nodes are involved. Prophylactic node resection is not employed routinely.

Reports from the literature probably do not represent the true incidence of carcinoma in a scar. Among twenty-five carcinomas of the hand reported by Mason,[2] seven were Marjolin's ulcers and eight were due to roentgen dermatitis. Of 239 collected cases reported by Mason, sixty followed trauma other than irradiation. Treves and Pack[3] reported thirty-four cases of carcinoma in burn scars, reviewed the subject in their comprehensive monograph and quoted reports by Baasner[4] of 190 collected cases of scar cancer (thirty-three following burns) and by Durand[5] of ninety cases of degenerated scars, seventy of which followed burns. Treves and Pack reported that at Memorial Hospital from 1917 through 1929 2 per cent of all epidermoid carcinomas originated in skin which had been subjected to thermal injuries and 0.3 per cent of all were basal cell carcinomas. Schrek[6] estimated from an analysis of cases from Pondville and Huntington Memorial Hospitals that 18 per cent of all malignant tumors in the scalp, trunk, legs and arms developed in pre-existing scars of burns, lacerations, surgical operative incisions and ulcerations. Twenty-five cases were reported by Roffo and Gandolpho,[7] fifteen by Paillas and Bonneau[8] and individual cases of malignant tumors occurring in scars have been reported by Halford and Gotshalk,[9] Niedelman,[10] Shore,[11] Robinson,[12] Fleming and Rezek,[13] Danzis and Freedman,[14] Browne[15] and by about twenty other authors in less accessible journals within the past twenty years. No reliable data exists from which the incidence of malignant ulcers in burn scars can be estimated. There is, how-

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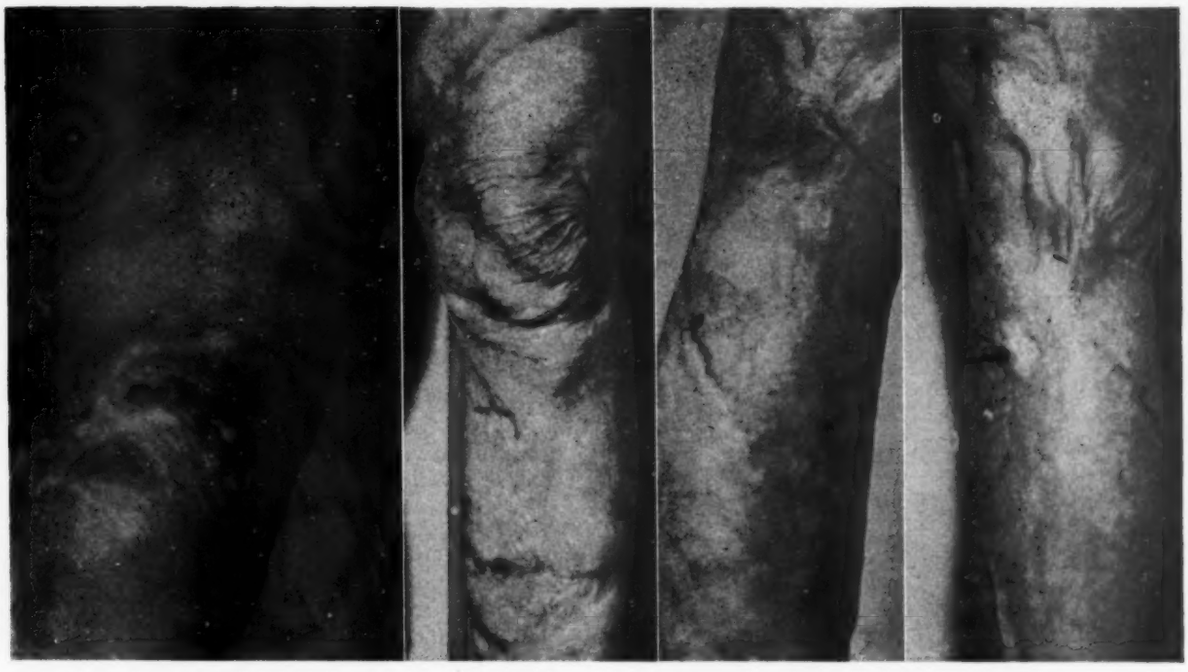

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FIG. 1. A, Marjolin's ulcer in a burn scar of the leg of twenty-five years' duration; B and C, anterior and medial views of the leg three years after resection and replacement with dermatome grafts; D, the arrow points to a depressed area in the posterior scar which is open to suspicion and may require excision later. Case I.

ever, some support for the opinion that any scar which is subjected to continuous trauma will eventually become malignant if the patient lives long enough.

CASE REPORTS

CASE I. D. W., a forty year old male, was burned severely at the age of fifteen years. The burns about the right thigh, knee and leg required more than a year to heal but skin grafts were not employed. After healing was complete, the scars about the knee and popliteal space were so tight that movement was somewhat limited. For five years prior to operation the dense scar in the region of the tibial tubercle (Fig. 1A) had broken down repeatedly and had finally remained open for two years. Examination showed two irregular ulcers on the anterior surface of the lower leg just below the knee. The larger one, 2.5 cm. in diameter, showed irregularly curled, indurated edges and a deep necrotic base. The smaller ulcer was more superficial. There was no significant enlargement of inguinal or femoral lymph nodes. Previous biopsies from the ulcers performed elsewhere had shown no evidence of malignancy.

The areas of ulceration were widely excised together with the bridle-like contracted scars which extended on each side of the popliteal space. With retraction of the relatively normal surrounding skin after removal of the dense scar, a large defect was created which required 90 square inches of free skin graft to cover (dermatome grafts of .016 inch thickness). Healing was complete within two weeks and the patient resumed normal activity within one month. Function of the involved knee gradually became almost equal to the unaffected one. Three years after operation he remained free from evidence of local recurrence or lymph node involvement. The microscopic section of the larger ulcer showed an area 2 cm. in length about the margin of the ulcer to be the seat of a well differentiated squamous cell carcinoma. (Fig. 1.) The smaller ulcer showed no malignant change.

CASE II. B. D., a male, twenty-five years of age, had a chronic ulcer on the anterior surface of the leg below the knee following a severe burn during infancy. The area had been excised elsewhere but the ulcer had recurred. At the time he was seen in consultation he presented a very large area of ragged ulceration about the inferior aspect of the knee joint which obviously extended into the knee joint capsule. (Fig. 2.) Sections confirmed the presence of squamous cell carcinoma. Amputation in mid-thigh and inguinal node dissection were performed elsewhere. No follow-up information on the patient is available.

CASE III. S. B., a female, sixty-six years of age, was burned severely on the back at ten years of age. A small area in the mid-lumbar region had never remained completely healed since the time of the burn. Upon examination she showed an area

FIG. 2. A Marjolin's ulcer of about eighteen years' duration in a young man; invasion of the knee joint necessitated amputation. Case II.

of dense cicatrix involving the lumbo-sacral region, with an indolent ulcer 3 cm. in diameter in its center. The surrounding scar was hard and areas of apparent calcification were palpable. No enlarged lymph nodes were palpable in either groin. The entire area was excised and replaced with 64 square inches of free skin graft. Even though the ulcer had been present for over fifty years, microscopic section showed only very early neoplastic changes. Three years after excision she was completely free from symptoms referable to the ulcer and in good health.

CASE IV. H. S., a male, forty-nine years of age, was admitted to the hospital for terminal care, presenting extensive burn scars of the right groin, abdomen and thigh. He had been hospitalized three years earlier because of a chronic ulcer in the burn scar which he had received thirty-five years before. The ulcer together with underlying lymph nodes had been excised and the defective skin grafted. At the time of his second admission the nodes had recurred and massive iliac nodes were palpable also. At autopsy the iliac nodes were extensively involved with poorly differentiated squamous cell carcinoma. No other metastases were found.

CASE V. V. Z., a male, thirty-nine years of age, complained of a draining sinus with ragged edges which had been present since childhood following an operation for osteomyelitis. (Fig. 3.) Roentgenograms showed moth-eaten destruction of the proximal tibia. Sections of margins of the ulcer

FIG. 3. A Marjolin's ulcer of about thirty years' duration in scars resulting from chronic osteomyelitis; extent of invasion necessitated amputation. Case V.

showed squamous cell carcinoma, unclassified. Mid-thigh amputation resulted in freedom from evidence of recurrence for ten years. Regional lymph nodes were not involved.

CASE VI. S. F., a colored, fifty-six year old female, was seen in consultation presenting a large, irregular ulceration with indurated borders just above the lateral aspect of the knee. The entire thigh and leg were the seat of extensive burn scars resulting from injury at eight years of age at which time healing was said to have required many months and skin grafts were not employed. There were several large, firm nodes palpable in the subinguinal region. The patient had first been seen in the outpatient department two years earlier presenting a very large ulceration on the lateral aspect of the thigh which was stated to have been present for only a few weeks. The area of ulceration was widely excised and the defect replaced with split-thickness skin grafts. The microscopic sections were reported as benign although in retrospect some criteria of malignancy were present. The ulcer recurred at the margin of the grafts and was again excised in a similar manner and reported as benign although showing changes suggestive of malignancy. Recurrence again was seen near the knee joint and resection this time showed unquestionable squamous cell carcinoma, moderately well differentiated. Following our observation the area was again excised and the sections showed invasion of the knee joint. Subtrochanteric amputation was then done. The regional lymph nodes showed no microscopic evidence of invasion. The patient remained free from evidence of recurrence or metastasis six months after amputation. (Fig. 4.)

CASE VII. F. S., a seventy year old, colored female, was admitted to the hospital for terminal care presenting a very large, fungating, necrotic lesion of the lower leg. (Fig. 7.) According to the history the ulcer had first appeared three months earlier in an area of atrophic, tight, mottled skin

over the tibial surface. It was assumed that the skin changes were due to vascular disease. The patient was emaciated and practically stuporous. There were numerous large, firm nodes in the inguinal and iliac regions and masses of nodes were palpable in the pelvis per rectum. Mid-thigh amputation was performed on the second hospital day and the patient died eight days later. No autopsy was permitted. Microscopic sections showed the lesion to be a moderately well differentiated squamous cell carcinoma which did not involve the tibia.

FIG. 4. A Marjolin's ulcer of only a few months' duration in scars resulting from frequent ulcerations of the lower extremity presumably due to chronic vascular disease. Case VI.

COMMENT

Five of the seven Marjolin's ulcers presented occurred in burn scars of twenty to fifty years' duration. All were squamous cell carcinomas. Lymph nodes were involved in the cases which were fatal. Cases I and VI illustrate the importance of thorough and frequent biopsies in doubtful cases. In retrospect, it seems likely that the ulcer in Case VI was malignant from the outset and probably already had invaded the fascia planes. It is suggested that in the case of suspicious-looking ulcers in scars of long duration such cellular changes as atypical epidermal proliferation, pearl formation and mitotic figures, even in the absence of clear-cut evidence of invasion, should be considered sufficient to warrant radical surgical treatment. Chances are that if the tissue block is sectioned methodically, some area of frank carcinoma will be found. Our experience as well as that of other observers would indicate that this type of carcinoma remains local for a long time and that radical surgical resection and skin replacement offers an excellent opportunity for cure or long survival if extensive regional or remote metastases have not already appeared. When local bone invasion has already occurred, amputation is the only practical method of treatment. From what evidence is available it seems likely that radical regional lymph node dissections are not necessary unless there is objective evidence of node invasion by carcinoma. In none of our cases of Marjolin's ulcer and in none of the reported cases we have reviewed had skin grafts been employed at the time of original injury. In no instance with which we are familiar has a Marjolin's ulcer occurred in any traumatic lesion which has been adequately skin grafted. It is apparently possible to prevent the occurrence of these ulcers by proper skin replacement even many years after the injury.

PREVENTION

Every cutaneous scar which is subjected to continuous trauma is a potential Marjolin's ulcer. In addition to constituting a threat to the patient's life, these scars are disabling and disfiguring. All of them can be prevented by the early skin grafting of granulating wounds and by replacement of contracted scars by one of the following means: (1) free grafts, (2) pedicle grafts or (3) Z-plasties.

Scars about the knee joint seem particularly prone to develop ulceration due to the tension of frequent movement but other common regions for Marjolin's ulcers are the face, neck, axilla, groin and foot. Free grafts and Z-plasties will relieve most of the scars that are dangerous but in some regions where maximum elasticity is demanded pedicle flaps are required. For replacement of scars about the anterior surface of the knee, leg and thigh, free grafts are usually adequate. (Fig. 1.) For popliteal contractures where skin loss has been extensive, pedicle flaps are frequently necessary. As a general rule free grafts are used by preference because of their simplicity and minimal time of

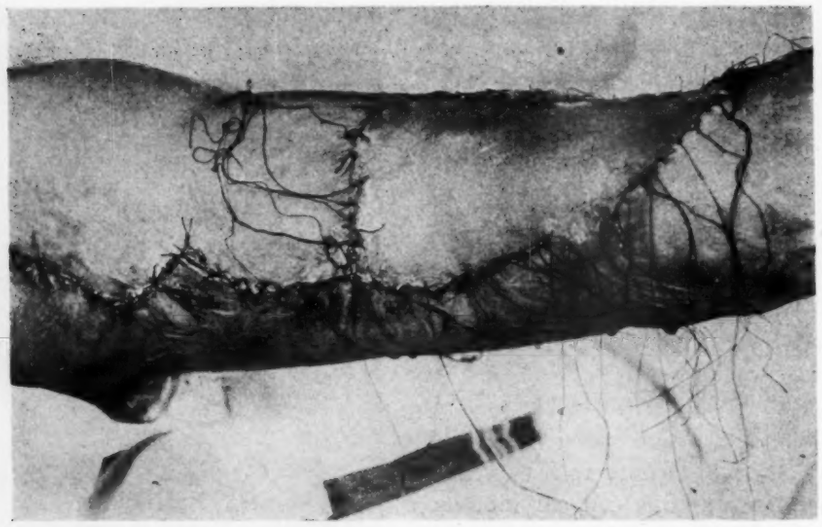
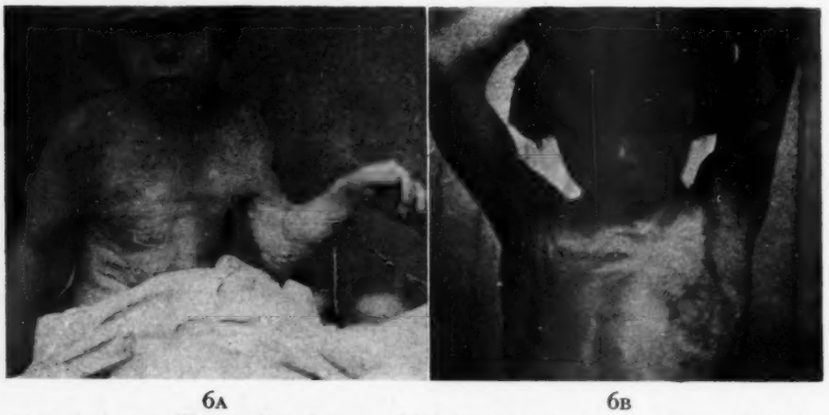


FIG. 5. Illustrates the combined application of a Z-plasty and a free graft in the correction of a contracted scar of the axilla and arm.



6A 6B

FIG. 6. A case illustrating the use of bilateral Z-plasties to relieve relatively narrow contracted bands of the axillae; A, before operation; B, after operation.

disability. In case of doubt a free graft is used and, if necessary, later replaced with a pedicle graft.

Axillary scars lend themselves particularly well to Z-plasties but again, where skin loss is great, the Z-plasty must be augmented by actual skin replacement. (Figs. 5 and 6.) Neck scars also occasionally lend themselves well to correction by sliding flaps or Z-plasties but only when the contracted scar is narrow and surrounded by elastic, normal skin. From a cosmetic standpoint there is no entirely satisfactory substitute for normal neck skin. Free grafts are, however, usually more satisfactory than pedicle grafts. (Figs. 7 and 8.) The preservation of the normal contour is all important in the neck and this can seldom be accomplished by means of pedicle grafts.

Free grafts are ordinarily quite adequate for extensive scars of the flank and groin (Figs. 9 and 10) but pedicle grafts are occasionally necessary. For weight-bearing surfaces of the foot, thick pedicle grafts are required and even these are far from perfect substitutes for the specialized plantar skin which has no counterpart elsewhere in the body. Plantar skin flaps require proper shoe fitting, special pads and rigorous foot care indefinitely.

We have not had conspicuous success with large, full-thickness, free grafts. The takes tend to be spotty and the end result is often not as good as that obtained with a thick split graft. When the latter is sutured into the defect carefully under somewhat less than normal skin tension, the resulting skin is usually of almost normal thickness and mobility after one or more years. The use of sponge rubber, as described by one of us previously,[16] renders the

7A 7B 7C

FIG. 7. A, a case illustrating the use of pedicle flaps for the replacement of neck scars; B and C, condition eight years after (A).

FIG. 8. A case illustrating the use of free grafts for the replacement of contracted neck scars; the postoperative photographs were taken eighteen months after operation.

application and fixation of these grafts relatively fool proof. (Fig. 12C.)

Roentgen irradiation of contracted scars which tend to break down is futile and dangerous as illustrated by the following case:

CASE REPORT

J. H., in 1923, at the age of thirty-nine, was severely burned about the face, neck, body and both upper extremities. The burns required almost a year for healing since no grafts were employed. From 1930 to 1935 he was given many x-ray treatments on "keloids" of both forearms. In 1940 he presented extensive malignant ulcers in the irradiated scars of both forearms which biopsies showed to be the seat of well differentiated squamous cell carcinoma. (Fig. 11.) Tendons and nerves of the left forearm were so extensively invaded that amputation just below the elbow was performed. The involvement of the right forearm was consistent with resection and replacement with a large abdominal flap. Bilateral axillary dissections were performed. The nodes showed no evidence of neoplastic invasion. When examined in 1949, the patient showed no evidence of recurrence but tight areas on his neck were beginning to break down.

This patient was continuously disabled for over a quarter of a century as a result of a condition which could have been prevented by the early use of skin grafts.

9A

9B

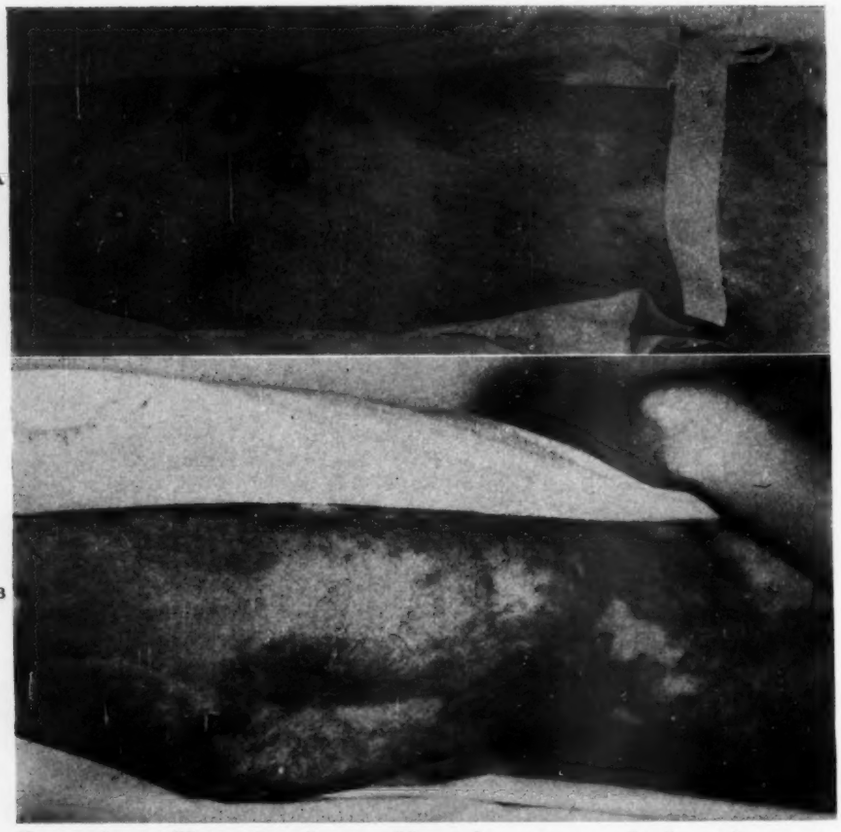


FIG. 9. A case illustrating the use of large dermatome grafts for replacement of a large, tight cicatrix of the chest wall, flank, groin and thigh; A, shows an ulcer in the center of the area of scar which had been present for several years but was not malignant; B, shows the appearance of the graft six months after operation.

10A

10B

10C

FIG. 10. A case similar to that shown in Figure 9 but without ulceration; both were burn scars of more than twenty years' duration. A, shows the appearance before operation; B, shows the scar excised and replaced with three dermatome drums of skin; the difference in size between the excised scar on the wooden block and the skin grafts required to replace it after complete relaxation was obtained is apparent; this photograph also illustrates the use of angles at irregular points in the scar in order to avoid straight lines at the margins of the grafts; C, sutures are left long and tied through and over sponge rubber cut to fit the defect. This method of application practically assures perfect contact of the graft with its bed.

FIG. 11. Bilateral carcinoma in irradiated burn scars of the forearms which required amputation on the left and replacement with a large pedicle flap on the right.

SUMMARY

1. Marjolin's ulcer, or carcinoma in a scar, occurs when the scar is subjected to continuous tension or other trauma for a period of years.

2. It is curable by radical surgery before the regional nodes are extensively involved.

3. Marjolin's ulcer is *always* preventable by appropriate transplantation of skin for closure of open wounds and by replacement of dense scars before they break down.

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DISCUSSION

GROVER C. PENBERTHY (Detroit, Mich.): Dr. Glover's and Dr. Kiehn's paper is very timely. It brings to our attention and emphasizes again the importance of the follow-up of all burn lesions, especially those that have been skin-grafted. It is timely because today, with the interest in and fear of cancer on the part of laymen and ourselves, this subject brings to our attention a problem that we must handle from year to year.

Dr. Glover has referred to cases of twenty-five years' duration. It is interesting to follow some of the children that we have had in Detroit and see them as adults coming back with a scar and ulcer. It is wise and intelligent to inform all parents that where their children have been burned and skin-grafted, the lesion may require subsequent attention in later years and to watch for this Marjolin's ulcer that Dr. Glover has called to our attention.

I think this paper to begin with is a timely presentation and leads us all to think that these burn

cases, whether they have been grafted or have been allowed to go without grafting, should be watched and followed-up over the years.

HAMILTON A. BAXTER (Montreal, Quebec): I would like to express my appreciation also for Dr. Glover's excellent presentation.

We have tried to follow the general principles which he has outlined in the cases we have seen. However, in our community certain attitudes exist among some, and I believe that they are widely disseminated, which we should strive to correct by constant repetition of certain principles to the general practitioners in our vicinity. So often we see these neglected cases too late. The attitude of prevention is the one that we should try to teach constantly to the general practitioners, each in our own area.

HARVEY S. ALLEN (Chicago, Ill.): It has been our good fortune, or ill fortune, to see many such cases as Dr. Glover has illustrated, and we, too, heartily endorse the program which he has outlined.

We have seen Marjolin's ulcer particularly in burns, which are the most commonly found source. The oldest that we have seen was in a burn of thirty-five years' duration. It had been opened constantly from the time of its inception, thirty-five years of chronic draining wound. The youngest that we have seen was one of eight years' duration.

We have also seen it following osteomyelitis with bone involvement, squamous cell involvement into the bone, in which case, there was wide excision of the bone and the scar and a delayed closure. This had been present for twenty-two years.

One point that I would like to stress and bring again to your attention, however, is that of the x-ray burn, the irradiated areas. Far too often these are neglected and the patient told that he will be perfectly all right when we know that on an average in fourteen years these, too, break down and become malignant.

TRUMAN G. BLOCKER, JR. (Galveston, Tex.): I would like to discuss two recent cases which we have had of ulceration occurring in old burn scar. The first lesion was of thirty-two years' duration and the fungating portion of the ulcer had been present for eight years. Microscopic section showed a sarcoma. At operation the defect was so large after complete excision of scar tissue that five drums of skin were required for complete coverage.

In another instance the patient had had a burn scar for thirty years which refused to heal. This was of the typical Marjolin type with squamous cell carcinoma. After wide excision in an effort to secure complete relaxation before closure we excised a number of little triangles from the scar edges before applying four drums of skin to cover the area. Dr. Glover mentioned this principle, employing angles or darts in the scarred borders of the wound, in order to relieve the contracture completely and prevent recurrence of scar bands in line of function.

JOHN E. CANNADAY (Charleston, W. Va.): The majority of ulcers of this type that I have seen and dealt with have been below the knee. They usually are very susceptible to traumatism, even to slight trauma. I have found that lumbar gangliectomy, which can be done extraperitoneally, facilitates healing very much, particularly when you come to applying skin grafts.

I have observed also that postural treatment can be of decided value in these conditions as, for example, getting the patient to keep the part of the limb involved elevated at a higher level than the body most of the time. This type of treatment if faithfully carried out materially helps to prevent recurrence.

DONALD M. GLOVER (closing): I wish to thank the discussers for their kind remarks and comments.

The time element, which has been mentioned by several of the discussers, is perhaps the key factor in the development of these ulcers. We do not know how long it takes for a malignant ulcer to develop. In one of our cases it occurred after fifty years. Another point is the similarity between Marjolin's ulcers and those which occur in irradiated areas. While irradiation carcinoma is not, strictly speaking, a Marjolin's ulcer from the standpoint of the original description, the mechanism is almost identical and there is no reason for considering them in any different light. The ulcers are open to suspicion as long as they exist and the only possible method of preventing malignant change is to get rid of the damaged tissue and get rid of it early.

In regard to the postural management brought out by Dr. Cannaday, I agree that in some cases it is helpful in preventing contractures. It is my conviction, however, that it is impossible to overcome loss or deficiency of skin by any other means than by actual replacement.

PERTINENT FACTORS INFLUENCING REPAIR IN TRAUMATIC WOUNDS*

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Troy, Ohio *Columbus, Ohio*

IN the book, "Marrow of Chirurgery," which was written in 1685, James Cook of Warick, "Practitioner in Physic and Chirurgery," defines a wound as follows: "A wound is a solution of unity in any part of the body by an external instrument. They receive their differences from their magnitude, part wounded and their cause."[1] It would be difficult to find a more concise and descriptive definition.

Excluding wounds deliberately made during surgical procedures, all wounds are soiled and potentially infected due to organisms carried in by the "external instrument" at the time of wounding. Fundamentally wounds caused by instruments of war are no different from those encountered in civilian life. It is a question of magnitude. Because of the jagged contour of shell fragments, war wounds are generally far more destructive than civilian wounds. Furthermore, much more foreign material such as dirt and soiled clothing is carried into the depth of the wound. With this foreign material a variety of most virulent pathogenic organisms may be introduced. The terrain and the patient's environment at the time of wounding may influence the type of organisms introduced and should be considered. In this connection one might reflect upon the increase in the incidence of virulent gas infection in Italy during World War II as compared with its almost non-existence during the African Campaign. Also, in war wounds the delay between injury and treatment is of necessity longer than usually encountered in civilian wounds, all of which adds up to a wound (Fig. 1) with marked tissue destruction which is soiled and in which the potentialities of infection are far greater.

In the early part of World War II every medical officer was treating patients according to his own individual plan and policy.[2] Some of the methods employed were very good while others were very poor. It was at this time that a follow-up study and evaluation of 498 battle casualties was accomplished. (Table 1.) This necessitated the visiting of twenty-eight American, British and French hospitals throughout

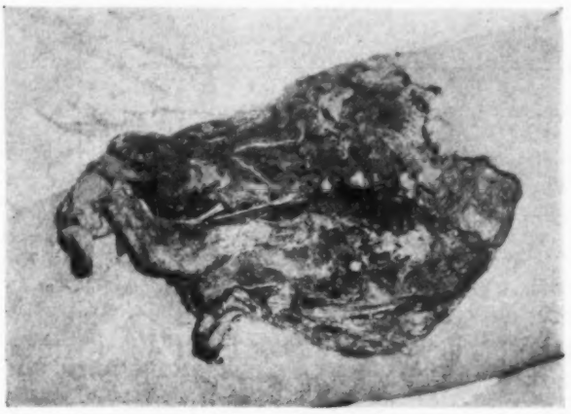

FIG. 1. Appearance of a war wound of the thigh showing marked tissue destruction and soiling. A severe invasive infection (clostridial myositis) has developed.

North Africa in addition to the Surgeons' offices in Algiers, Oran and Casablanca. Thus an excellent opportunity was provided to evaluate some of the fundamental principles and pertinent factors influencing the repair of over 1,000 traumatic wounds.

This follow-up study in addition to observations on a large number of other patients treated by other surgeons revealed numerous professional sins of omission and commission some of which were still in evidence in the European theater as late as February, 1945. Briefly, these were: (1) an improper concept of débridement; (2) saucerization or sacrifice of too much skin; (3) plugging of the débrided wound with sulfanilamide powder, vaseline gauze or both; (4) primary suture of débrided wounds; (5) tampering and fussing with the wound either before or following débridement; (6) insufficient immobilization of the débrided wound and (7) an almost total ignorance of the procedure known as delayed suture. With the exception of the overuse of sulfanilamide it is

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interesting to note that our attention was directed to these same errors following World War I.[3]

DÉBRIDEMENT

Undoubtedly the greatest hazard to healing encountered in traumatic wounds is infection and certainly a most important factor in eliminating infection is a thorough débridement. It has been our belief that the principle of débridement is the same regardless of whether we are dealing with a military or civilian wound. On the other hand, the extent of the application of that principle may differ in the two types of wounds. It is our impression that the débridement of a wound is an operation of incision and excision. (Fig. 2.) The skin is incised in the long axis of the limb. Unnecessary sacrifice of tissue, especially the skin, should be avoided as it is particularly resistant to infection. The wound is then incised or enlarged until its full extent is visualized. The enlarging is carried out in the direction of fascial planes and muscle fibers. All foreign

TABLE 1
PERTINENT FACTORS INFLUENCING REPAIR IN TRAUMATIC WOUNDS*

	Per Cent of Total	Interviewed	Duty	Limited Duty	Z.I. (U.S. or U.K.)	Deaths	Per Cent Fatality	Total
Debridements (Soft tissue)	47.7	58	134	11	29	0	0	232
Compound fractures	24	22	10	4	72	2	1.8	110
Simple fractures	2	..	3	..	7	0	0	10
Thoracic (penetrating or perforating)								
a. Sucking	....	3	4	..	7	3	9	33
b. Non-sucking	6.6	1	8	1	6	0		
Amputations	6.4	2	2	..	25	3	9	32
a. Shoulder 2		1 also had sucking chest injury						
b. Arm 4								
c. Forearm 3								
d. Thigh 4		1 also had head injury and 2 had abdominal injury						
e. Leg 20								
f. Foot, fingers, toes 3								
Abdominal	5	4	2	2	12	5	25	25
a. Colon only 4	....	..	...	..	..	1		
b. Small bowel only 3	....	..	...	..	..	0		
c. Colon and small bowel 6	....	..	...	..	..	3		
d. Colon and stomach 2	....	..	...	..	..	0		
e. Colon, stomach and liver 1	....	..	...	..	..	0		
f. Liver 1	....	..	...	..	..	0		
g. Liver and kidney 1	....	..	...	..	..	0		
h. Spleen 1	....	..	...	..	..	1		
i. Abdominal injury without visceral perforation 6	....	..	..	..	..	0		
Thoraco-abdominal (Sucking chest, diaphragm, spleen, liver, stomach, colon, small bowel)	.8	..	...	..	2	2	50	4
Abdomens not operated (Moribund)	.4	..	...	..	..	2	100	2
Head	4.4	1	4	3	7	7	33.1	22
Head and chest	.2	..	...	..	..	1	100	1
Maxillo-facial	3	2	6	1	6	0	0	15
Burns	1.2	3	3	..	..	0	0	6
Gas infections	.8	1	...	..	3	0	0	4
Spinal cord	.4	..	...	..	1	1	50	2
Totals	....	..	...	..	..	26	....	498

material, traumatized and devitalized tissue including muscle and unattached bone fragments, are meticulously removed or excised. (Fig. 3.) If the wound is properly débrided, this principle must be followed relentlessly and may in certain instances even necessitate the

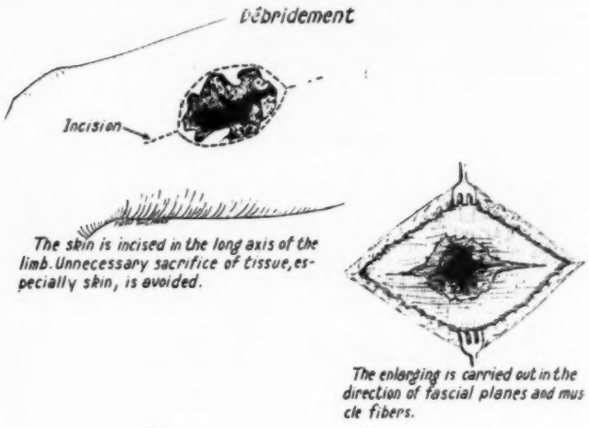

Débridement
Incision
The skin is incised in the long axis of the limb. Unnecessary sacrifice of tissue, especially skin, is avoided.
The enlarging is carried out in the direction of fascial planes and muscle fibers.

FIG. 2.

Of 228 patients with uncomplicated soft tissue wounds, 134 were returned to full duty and eleven to limited duty. Of those returned to full duty, the longest period of hospitalization was 125 days and the over-all average was 39.3 days. Of those returned to limited duty, the

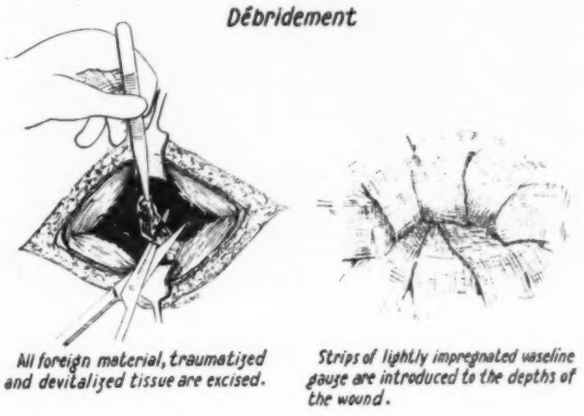

Débridement
All foreign material, traumatized and devitalized tissue are excised.
Strips of lightly impregnated vaseline gauze are introduced to the depths of the wound.

FIG. 3.

removal of an entire muscle or muscle group. (Fig. 4.) Direct vision of the extent of the wound not only assures us that major nerves and blood vessels will be preserved but also that hemostasis will be rigidly secured. (Fig. 5.)

Lest it be thought that these ideas are new, the following statement is quoted from "The Marrow of Chirurgery" published in 1685: "Cure is performed, first, by removing extraneous bodies which are so either by accident, as contused flesh, clotted blood, bones, gristles, pieces of membrane, tendons or hairs, or of their own nature, as pieces of garments, weapons, steel, lead, shivers of wood, gravel, etc. These are to be removed, such as may be by washing, others by forceps."[1]

Experience has certainly proven the efficacy of gentle but thorough cleansing with soap and water followed by copious irrigations with sterile saline or water.

In Table 1 it is noted that there were 232 casualties whose wounds were limited to the soft tissues and who, therefore, were classified as débridements. Most of these were major in extent involving deep muscle and fascia. Of the twenty-nine patients who had been evacuated to the Zone of the Interior, nineteen had wounds which were quite extensive, involving the upper thigh and buttocks. Two had complicating eye injuries, two severe nerve injuries and three had developed a psychoneurosis. The remaining three patients had very severe infections in their wounds.

average period of hospitalization was 52.8 days, the longest period being 127 days. There were 266 casualties who had other major injuries (thoracic wounds, abdominal wounds, etc.) in addition to their soft tissue wounds. It should be emphasized that virtually all of these had

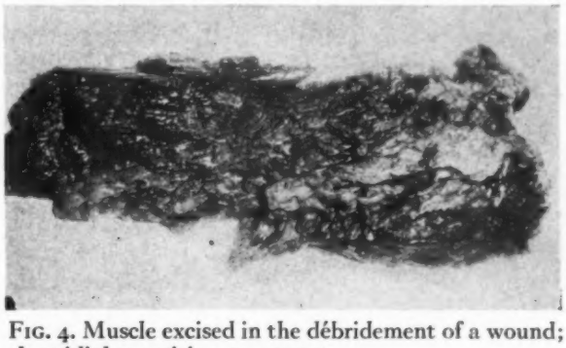


FIG. 4. Muscle excised in the débridement of a wound; clostridial myositis was present.

one or more wounds which required débridement. (One casualty had thirty such wounds).

This study revealed that with the exception of wounds of the hand, face or scalp, primary suture *should never be utilized* in war wounds. Even when aseptic excision *en bloc* procedures were accomplished, 50 per cent of those primarily closed became infected. Following débridement it was learned that the wound may be lightly dusted or frosted with sulfanilamide crystals and this in turn covered with lightly impregnated vaseline gauze introduced to the depths of the wound. (Fig. 3.) This amply allows for drainage. The vaseline gauze may

then be covered with fluffed sterile gauze and a pressure dressing applied; lastly, the wound should be well immobilized by means of a plaster splint or encasement. If the latter is used, the importance of splitting or preferably bivalving the cast cannot be overemphasized.

The blind digital exploration of a wound tract while looking to the heavens for divine guidance has no place in débridement.

FIG. 5.

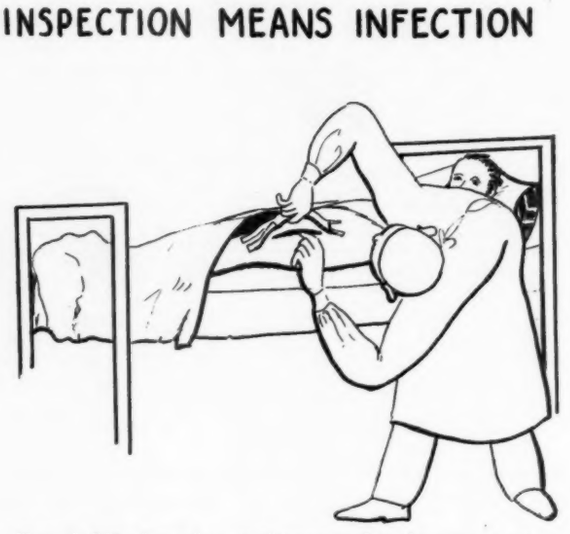


FIG. 6. The impulse to change a dressing or to peep at a wound is difficult to resist. However, the statement, "inspection means infection," is so important that it should be impressed upon the mind of every surgeon charged with the care of open traumatic wounds.

SECONDARY WOUND INFECTIONS

Another pertinent factor which delayed wound healing in this series of patients was secondary wound infection. It is first essential that the basic difference between primary and secondary wound infections be fully appreciated.[4] Primary wound infections are those caused by bacterial contamination at the time of injury. These bacteria are derived from the soil, clothing, skin and foreign bodies. Secondary wound infections, on the other hand, are those caused by bacteria introduced into the wound at any time after the initial injury.

These secondary infecting invaders may come from the respiratory tract of the patient, the unmasked nurse, surgeon or ward attendant. They may come from the skin of anyone touching the wound or from unsterile instruments and dressing exposed to dust-laden air. Dust kicked up from the floor by a passing attendant or air currents created by movements of the patient or his bedclothes, during inspection and dressing are also possible sources of secondary organisms.

DeWaal[5] in a bacteriologic investigation of 708 wounds found that when first-aid "cleansing" of wounds was done, more than twice as many infections occurred as when the wound was simply dressed without any attempt to "cleanse" it. Edwards[6] and others[5,7] noted a decided increase in infection in those wounds which were redressed *en transit* from forward to base hospitals over those which had not been disturbed. At the time of this follow-up study it would almost have been considered negligence, if the ward surgeons did not inspect, redress and otherwise tamper with the patients' wounds. When these patients were interviewed and their wounds inspected at base hospitals, none were found who thought that their injuries had been neglected. At each hospital to which they had been admitted for a few hours or days in their long evacuation en route from Tunisia, their soiled dressings had been replaced by fresh ones and quite frequently their dirty and somewhat uncomfortable casts had been replaced by new ones. This is not offered as a criticism. It was the generally accepted policy.

Caldwell[4] has stressed an appalling incidence of secondary infections in hospitalized patients with open wounds stating that it is actually the principal cause of delayed healing and impaired function. It was his opinion that at least half of the serious, persistent infections in wounds were caused by bacteria secondarily introduced. He found only 5 per cent of fresh wounds infected on admission to the hospital but after a week in the institution 50 per cent of the wounds contained secondary invaders;

later they were found in 70 to 80 per cent of open wounds.

The impulse to change a soiled dressing for a clean one or just to peep at the wound is only natural and most difficult to resist. However, the statement "Inspection Means Infection" is one of such importance that in some manner it should be permanently impressed in the mind of every surgeon charged with the care of open traumatic wounds. (Fig. 6.)

DELAYED SUTURE

The evolution of the concept of delayed suture was slow and fraught with confusion and little was carried forward from experiences during the last war.[9–11] Several different formalities, technics or methods of closure were utilized, each having its ardent advocates. One of these, consisting of preliminary inspection, bacteriologic cultures of wound flora and preliminary wet dressings, was used in World War I and has been described in detail by Pool.[9] Although this routine was used to some extent in World War II, *a noteworthy contribution to wound management has been the revelation that this procedure or any part of it is not only unnecessary but actually detrimental to best results.*

In this series of 498 patients in whom a follow-up study was conducted there was, to our knowledge, not one single instance in which the patient's wound or wounds had been given the advantage of delayed suture. This program had not as yet been initiated so all wounds were allowed to heal by granulation. Many of those patients whose wounds had healed at the time of our interview had developed deep, deforming, contracted scars which required extensive physiotherapy and rehabilitative measures. (Fig. 7.)* Capper[8] in a small series of unselected thigh wounds found that the average time away from duty was 104 days for unsutured wounds and eighty-eight days for those which had been sutured. Furthermore, 90 per cent of those patients whose wounds were sutured returned to full duty compared with 54 per cent of those whose wounds were not sutured.

While several factors appear to influence the relative success of delayed suture, Lowry and Curtis reported a subsequent analysis of 721 wounds sustained by 360 consecutive, unselected patients which revealed that the most important single factor was the time interval between the initial surgery and the delayed suture.[12] This analysis revealed that the optimum time interval in which to close a wound was four to five days following the initial surgery. At this time the tissues were found to be soft and pliable; moreover, they could be approximated without resorting to wound trimming, excision or undermining. Beyond the optimum time interval this analysis revealed that the wound edges soon became fixed with an inversion of the epidermis. Trimming and excision with extensive undermining were often necessary to effect approximation without tension. The prolonged time interval with the added trauma required to accomplish a delayed suture resulted in a pronounced drop in percentage degree of healing. Moreover, they found that when wounds were closed prior to the fourth and fifth day (97 per cent healing) optimum time interval, only 86 per cent healing occurred.

FIG. 7. Deep, deforming, contracted scar present in a wound which healed by granulation.

This observation is quite striking in the light of the experimental work of Berman and his associates.[13] They found that a localized immunity against infection was not present in wounds up to twenty-four hours old but began on the second day, increasing to attain 100 per cent on but not before the fourth day.

It is admitted that many traumatic wounds occurring in civilian practice may be safely

* Figures 1, 4, and 7 were made by photographic units of the Museum and Medical Arts Service of the U. S. Army Medical Museum. Figures 2, 3, 5 and 6 were prepared by the Department of Photography from illustrations drawn by William F. Shepard, Medical Illustrator of The Ohio State University.

closed immediately following their débridement. If, on the other hand, healing approaching 100 per cent can be obtained by utilizing delayed suture,[12] it would appear that those wounds associated with marked tissue destruction and severe contamination or a prolonged time lag between injury and treatment should best be left open for delayed suture. Furthermore, it appears not only possible but desirable in some instances to extend the application of delayed suture well beyond the realm of traumatic surgery; for example, McLachlin[14] has demonstrated quite conclusively the advantage of delayed suture in diabetic gangrene. Several surgeons, including ourselves, have utilized delayed suture in the abdominal wound of patients suffering from ruptured appendicitis with localized or generalized peritonitis. It has also been used with advantage in the treatment of patients with pilonidal sinuses. It therefore appears that in any wound in which there is risk of infection it may be more safely handled by waiting until localized immunity has fully developed before attempting a closure.

World War I experience dictated that preliminary bacteriologic cultures should be accomplished on all wounds before a closure is attempted. It is admitted that these rather time-consuming studies are of investigative interest and they have contributed much to the fundamental knowledge of wound management. However, except in the presence of an established gross infection, routine bacterial cultures of the wound flora are of no practical value. Even in the absence of gross infection, streptococcus, staphyloccus, proteus, pyocyaneus and even clostridial organisms are frequently found and have been shown to persist in these traumatic wounds[5] yet seldom interfere with healing.[15,16]

WET DRESSINGS

Since the dawn of modern surgery the search for the ideal antiseptic has been constant and universal. It is well known that the ability of most antiseptic agents to sterilize a wound is at best questionable. Many which are highly efficient in a test tube show less efficiency in a wound. Moreover, most antiseptic agents which are bacteriocidal exert an equally damaging influence on the tissue thus creating an excellent culture medium for surviving organisms.

During World War II the evolution to our present concept of delayed suture included a period during which open wounds, although appearing grossly clean, were subjected to various types of wet dressings. These were changed daily for forty-eight to ninety-six hours prior to delayed suture. In some quarters it appears that this practice persisted until the end of the war. Our experience with this formality is limited to eighty-three clinically clean wounds only eight of which are included in the series of 721 wounds previously mentioned. Each wound was evaluated on a degree of percentage basis and no wound was considered 100 per cent healed unless primary repair had occurred throughout at the time the sutures were removed. Only 79 per cent healing was obtained in those wounds in which preliminary wet dressings were used as compared to 91 per cent in all wounds in which they had not been used. While this experience is small, it was sufficiently discouraging so the practice was entirely abandoned unless there was obvious evidence of infection when the patient was first examined or when his initial dressings were removed in the operating room.

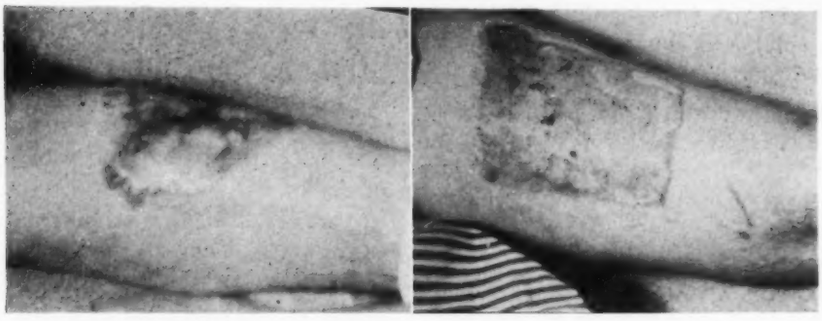
Therefore, it appears that the application of any wet dressings to an open wound introduces the hazard of secondary invaders, prolongs the important time interval between initial surgery and delayed suture and certainly, as in this study, results in a reduced percentage of healing.

INFECTIONS

If wet dressings are utilized at all, they should be reserved for those wounds in which gross infection is present. As previously reported[12] infections were present in 15 per cent of the preoperative and 21 per cent of 721 postoperative wounds.

At the present time some investigative work with Bacitracin* is in progress in pre- and postoperative wound infections. In the more severe, localized infections bacitracin solution, 500 units per cc. in combination with 1 per cent novocain, is infiltrated around the site of the infection in quantities of 5 to 10 cc. Twenty cc. have been used with no deleterious effect. The range of antibiotic activity of bacitracin is in general similar to that of penicillin. On the other hand, there are some penicillin-resistant

* This antibiotic agent was first reported by Meleney and co-workers in *Science*, 102: 376, 1945. It has been supplied through the generosity of C. S. C. Pharmaceuticals, a division of the Commercial Solvents Corporation, New York 17, N. Y.



8 9

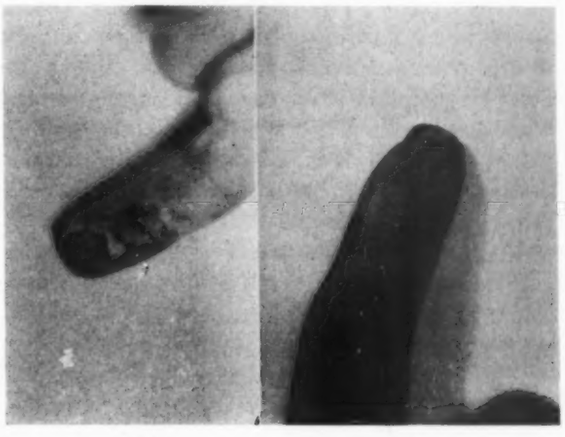
FIG. 8. Traumatic wound of leg with considerable loss of skin after primary suture. Secondary debridement, secondary suture, and skin graft; loss of portion of skin graft; epithelization promoted with chloresium solution and ointment. FIG. 9. Same case as Figure 8. Skin graft cut too deeply; epithelization promoted with chloresium solution and ointment.

organisms which are bacitracin sensitive. The solution is prepared by mixing with 2 per cent novocain a previously prepared stock solution made up with sterile saline in a concentration of 1,000 units per cc. Just prior to infiltration one-half of the desired quantity of bacitracin is mixed in the syringe with an equal quantity of 2 per cent novocain. Very little discomfort has been experienced. The infiltration is supplemented with topical applications of the solution. Fine mesh gauze is introduced into the depth of the wound which is covered with a piece of sterile rubber sheeting. At intervals of three to six hours the rubber sheeting is lifted and the gauze resaturated with 1 to 5 cc. of the solution as required.

In wounds with less severe infections topical applications of the solution or ointment have been utilized. The solution has appeared to be slightly more efficacious so in hospitalized patients it is generally used in preference to the ointment. Furthermore, infiltrations appear to possess distinct advantages over topical applications alone.

The number of wounds thus treated is too small for us to arrive at any definite conclusions but the results have been much superior to those in which one of the usual wet dressing solutions had been used. At the end of twenty-four to seventy-two hours the wound usually appears clinically clean and ready for delayed or secondary suture or skin graft. (In a wound previously sutured the term secondary suture applies.) It should be emphasized, however, that the same error should not be committed as occurred with the sulfa drugs. Bacitracin has not replaced any of the fundamental principles of good surgery. Adequate drainage with the removal of all necrotic and devitalized tissue still remains the keynote in the management of infected wounds.

Some clinical investigation is also in progress with chloresium.* In certain instances when partial loss of a skin graft has occurred (Fig. 8) or when the skin graft has been cut too deeply resulting in a delay in epithelization of the donor site (Fig. 9), chloresium has been utilized advantageously. Other instances of traumatic wounds of the digits and elsewhere in which a loss of epithelium has occurred have been encountered. (Fig. 10.) When this loss has not been too extensive, daily applications of chloresium ointment have been utilized rather than hospitalizing the patient and doing a skin graft.



10A 10B

FIG. 10. A, loss of skin in traumatic wound of index finger; B, entirely healed fourteen days later.

* Chloresium is the trade name for the water soluble chlorophyll derivative preparation used in this study. It has been supplied through the generosity of the Rystan Company, Inc., Mt. Vernon, N. Y.

Again the series of wounds in which this preparation has been applied is too small for final evaluation. Nevertheless, the results thus far obtained have been impressive. This limited experience indicates that the lag phase of repair is shortened and that epithelization is definitely accelerated.

PRESSURE DRESSINGS

In the two series of wounds under consideration the dressing was quite important and, if properly applied, was a definite aid to healing. A certain amount of edema is invariably present in traumatic wounds following débridement and at the time of closure. Any undermining of the skin edges or revision of the wound is almost certain to be attended with increased loss of local fluid or exudation. This increase in local edema naturally leads to an increased tension of the suture line. Tissue approximated under tension is notorious for its failure to heal. Furthermore, tissue which is boggy with edema will not heal. Therefore, it can be readily appreciated that every effort must be made to minimize and decrease local edema following a delayed suture or skin graft. A pressure dressing with mechanics waste and an elastic bandage was found ideal as it not only retarded the loss of local fluids but also tended to reduce the edema already present.

The favorable influence of selective, purposeful mechanical pressure on wound healing was discussed by Blair[17] in 1924. He listed four basic ends to be gained: (1) elimination of dead spaces; (2) control of oozing; (3) limitation of stasis and (4) limitation of the amount of plastic substance that pours into the wound. Of additional interest was the observation of Twyman[18] that epithelium proliferates readily when subjected to a pressure that restrains the growth of connective tissue. Thus by regulating the bandage pressure to an amount which corresponds to that required to blanch the finger nail, the granulation capillaries are compressed or collapsed and the tissue is repressed while epithelial growth proceeds unaffected.

Elevation of the extremity postoperatively for a minimum of twenty-four to forty-eight hours is, on theoretical grounds, an adjunct in decreasing local wound edema. This aids in draining lymph and venous blood by gravity thereby relieving stasis and improving local circulation.

IMMOBILIZATION

It has been previously mentioned that traumatic wounds should be well immobilized especially following débridement. The lack of adequate immobilization was one of the major errors of omission in the early phase of World War II. (Table I.) The contrast in the comfort of the patient and the appearance of the wound between those patients whose wounds had been properly immobilized and those in whom this pertinent factor had been omitted was most striking.

Following delayed suture immobilization is also a definite adjunct to wound healing. It prevents the disruption of fibroblastic and vascular strands of new tissue by movement or tension. In wounds complicated by fracture, nerve or tendon suture and in wounds involving or in the vicinity of joints, immobilization should be absolute and in a position favoring function and approximation without tension. However, in most uncomplicated, soft part wounds it was not found necessary to practice rigid splinting in plaster encasements or moulded splints. Pressure dressings with the patient's cooperation at bed rest provided the immobilization required for firm and rapid wound healing. After twenty-four to forty-eight hours of elevation the limited movement which a patient at bed rest may give a sutured extremity encased in a pressure dressing is advantageous in that it favors lymphatic drainage which further reduces wound edema. Furthermore, adhesion of sutured skin to underlying tissue was thereby discouraged which, with early ambulation after suture removal, considerably lessened the need for extensive physiotherapy. Modified rather than absolute immobilization of uncomplicated soft tissue wounds was apparently a contributing factor in the earlier return of these patients to duty.

BLOOD

The life-saving value of blood replacement in trauma and in all major surgical procedures is now generally accepted. At the time of the follow-up study, illustrated in Table I, this vital item was conspicuous by its absence in the forward areas (clearing stations) where the initial surgery was accomplished. Some few very major casualities received 500 cc. (rarely more) of blood obtained from the personnel of the clearing station or attached surgical

team. Plasma and glucose were available and certainly contributed to a lower mortality than would otherwise have been experienced. Later, as field hospitals became available, blood banks were organized.

It would be difficult to estimate the immense contributions which available blood replacement made during World War II. Of 375,000 battle casualties in the European theater who lived to reach a medical installation, the mortality was 3.9 per cent as compared to approximately 10 per cent in World War I.[19] While several factors contributed to this remarkable drop in mortality, a major one was probably the improved understanding of shock and its resuscitation with plasma and blood. On many occasions we have observed wounded soldiers brought into the field hospital more dead than alive. They were cold, listless, ashen gray in color and neither a pulse nor blood pressure was obtainable. At times their state of shock was irreversible but frequently under the influence of blood and plasma, which was pumped into three or four veins simultaneously, they have revived, undergone a major operative procedure and lived. (One personal patient who survived received 5,500 cc. of blood before, during and immediately following his surgery.)

The subsequent analysis of 360 patients with 721 traumatic wounds was accomplished in an overseas base hospital approximately two years after the follow-up study recorded in Table 1. During this period many notable improvements in the care of wounds had been accomplished.

The majority of patients with soft parts and fracture wounds arrived on the third to the sixth day following their débridement. Although most of them were in excellent condition, a few were quite ill with an established sepsis, a gas infection or a secondary hemorrhage which demanded immediate attention. Therefore, early examination and evaluation became mandatory.

In evaluating these patients considerable importance was attached to their hemoglobin, hematocrit and plasma protein determinations. The rapid copper sulfate method of calculating these values described by Phillips et al.[20] had been introduced and proved most satisfactory. From these determinations their requirements of fluid, plasma and blood could be outlined fairly accurately. Fortunately, good copper sulfate was provided and an excellent chemist to make up the stock solution was available.

Aware of the urgency of early wound closure, every effort was made to prepare these patients for surgery as rapidly as possible. Virtually all of the more severely wounded needed blood in varying amounts of from 500 to 2,000 cc. *It became evident that blood replacement was fully as important as chemotherapy in controlling infection and promoting wound healing.*

HYPOPROTEINEMIA

Protein deficiency as determined by reduced plasma protein determinations was present in most of the seriously wounded patients on admission to the hospital. This was surprising in view of the seemingly adequate blood and plasma many had received at forward hospitals. While uncorrected blood loss and initial surgery contributed, a major cause for this deficiency must have been an inadequate diet.[21] It has been previously mentioned that every effort was made to correct their hemoglobin, hematocrit and plasma protein levels before operation but it was frequently astonishing to find low determinations again following surgery.

The retarding influence of hypoproteinemia on wound repair is now well established. Elman,[21] Meyer and Kozoll,[22] Davis[23] and others[24–26] have thoroughly reviewed and stressed the frequency, recognition, prevention and treatment of this challenging issue in recent contributions. Clark[27] found that on a high fat diet wound healing did not begin for six days while on a mixed diet it began in four days. On a high carbohydrate diet the quiescent period was three days while on a high protein diet healing began at once. Thompson, Ravdin and Frank[28] in 1938 found that on a low protein diet abdominal incisions in eight of eleven dogs failed to heal. In 1940 Ravdin[29] stated that cellular repair and regeneration require protein and that in the absence of adequate amounts of essential amino acids growth cannot occur.

Protein metabolism is also concerned with resistance to infection.[25] Elman[21] has pointed out that lowered resistance to infection is demonstrated by the fact that the production of antibodies is but one-third to one-fifth as great in protein-deficient animals as in animals on a regular diet. He concludes that probably many postoperative infections may be due in part to a lowering of the immunologic response of the body secondary to protein starvation. Thus while virtually all of the partial to com-

plete failures in this study were attributed to infection, it is quite probable that at least some of these postoperative infections were due in part to protein deficiency. Elman has further pointed out that although hypoproteinemia occurs frequently after injury or surgery, its existence may often be masked by an associated dehydration or an increase in the globulin fraction due to an infection.

In this connection another factor of importance emphasized by Metcalf and Starr[26] is that the total plasma volume should also be known to interpret a plasma protein determination correctly. Thus 6 Gm. per 100 cc. in a patient with a plasma volume of 2,000 cc. is considerably different (60 Gm.) from the same value in another patient with a plasma volume of 1,000 cc. Therefore, in conditions associated with plasma and blood loss such as acute hemorrhage (intestinal bleeding, lacerated vessels and skeletal trauma) or local plasma loss (burns and peritonitis), the total plasma volume might be quite diminished yet the plasma protein determination might not reveal a marked reduction.

Adequate diet and multivitamin intake was encouraged in our patients in a deliberate effort to maintain their general resistance at a high level. When a reduced plasma protein determination was noted with unaltered hemoglobin and hematocrit values, intravenous plasma was used in an attempt to repair the protein deficiency. While it appeared that this method of treatment was quite effective, it is now recognized[25] that more efficient methods are available. Up to 150 Gm. or more of protein per day may be given intravenously in the form of hydrolysates or amino acids to which may be added glucose for its protein-sparing effect. Oral or, if necessary, tube feedings utilizing one of the skim milk powder formulas have been employed extensively and have been found to be not only economical but also a very satisfactory method of treating protein deficiency.

CONCLUSION

The history of the healing of a wound is the history of surgery.[30] At any rate it is a fundamental subject and one which has received increasing attention during the past few years. Arey[31] in 1936 presented a most comprehensive review which reveals many of the factors which may influence wound healing. Therefore it would appear advantageous to reflect for a moment on the factors which influenced repair in these traumatic wounds and translate, if possible, this military experience into a concrete plan of management which could apply in any traumatic wound.

From the moment of a wound's inception this one objective should be uppermost: prevent infection and preserve life and limb. This may be accomplished by full application of every means at the surgeon's command and begins with the first aid treatment at the scene of injury. This should include the control of pain by hypodermic and the control of hemorrhage by pressure or tourniquet, the application of a firm sterile dressing with *no attempt at preliminary cleansing* and immobilization of the wounded part. Resuscitative measures such as hot drinks and intravenous plasma may be utilized if indicated and available. In transit to the hospital the patient's body heat should be preserved with the judicious use of warm blankets. Reinforcement or readjustment of dressings may be necessary but the error of a change of dressing (except for continued active hemorrhage) is *strictly avoided*. With the patient's arrival in the hospital further resuscitative measures including a correction of reduced blood volume are employed as indicated. The patient is routinely given prophylactic tetanus antitoxin or a stimulating dose of tetanus toxoid. Such fluoroscopic and x-ray examinations as are indicated should be accomplished when the patient's condition permits.

Having determined the extent and circumstances under which the injury was incurred, a thorough débridement of the wound with meticulous removal of all devitalized tissue and foreign bodies is accomplished. To supplement the effectiveness of initial surgery in minimizing or preventing infection, bacterial proliferation is arrested through the intelligent employment of local and systemic chemotherapy (or antibiotic therapy). If the tissue is severely traumatized and the wound grossly contaminated, it is wisely left open with lightly impregnated vaseline gauze strips introduced to its depths thus providing for adequate drainage. Lastly the wound is well immobilized. Following the initial surgery inspections of the wound and redressings are rigidly avoided (unless a secondary hemorrhage or an unexplained sepsis develops) thus excluding the probable introduction of secondary infecting organisms.

At the end of four to five days the patient is again removed to the operating room where his dressings are removed and the wound evaluated upon its gross appearance alone. If the wound appears clinically clean, it may be closed by delayed suture and a pressure dressing applied; and healing approaching 100 per cent may be anticipated.

SUMMARY

Clinical observations on two series of patients with a total of over 1,700 traumatic wounds have been presented in an effort to emphasize some of the pertinent factors influencing wound repair. These factors have included (1) a correct concept of débridement; (2) the hazard of secondary wound infections; (3) the indications and advantages of delayed suture; (4) the use and abuse of wet dressings; (5) the importance of pressure dressings; (6) the desirability of immobilization; (7) the value of blood replacement and (8) a re-emphasis of the role of adequate protein levels in wound repair.

Most of these observations are based upon military surgical experience. On the other hand, it appears to us that the same fundamental principles of management apply to any traumatic wound regardless of whether it is military or civilian in origin. It is admitted, however, that the extent of the application of those principles may differ in the two types of wounds. The time lag, extent, magnitude and location of the wound, as well as the environment of the patient and the type of clothing worn at the time of wounding are all pertinent factors which will influence the extent of the débridement. Furthermore, these same factors will decide whether the wound may be closed by primary suture or left open until a localized immunity has developed and then closed by delayed suture.

If these fundamental principles and pertinent factors are constantly borne in mind, it is the opinion of the authors that the surgeon or physician responsible for the care of traumatic wounds will be rewarded by less infections, less disability and a much earlier return of the patient to his usual employment.

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DISCUSSION

Howard E. Snyder (Winfield, Kan.): I have enjoyed this paper very much. I think it should be said that the report you have just heard is probably unique in that shortly before the termination of the African campaign, Dr. Lowry set about to do an accurate follow-up on the cases that had received care by himself and his brother and several other surgical teams in southern Tunisia. The comparison of that early group with a later group is certainly a good one.

The points he has enumerated are certainly fundamental in war surgery and do not need further emphasis. I would like to have Dr. Lowry's opinion as to whether he still believes that vaseline gauze is the best material to place in the wound which is left open after débridement. In the latter months of the war it became the practice with many of us to employ fine-mesh gauze without vaseline. It was the impression of the base surgeons in our area that these wounds came back in even better shape than did those in which vaseline gauze had been used.

It might also be emphasized that the use of sulfonamide in the open wound was entirely discontinued in our theatre.

Vinton E. Siler (Cincinnati, O.): The subject of the treatment of traumatic wounds covers much territory. I would like to ask Dr. Lowry one question, if he believes that many of these fundamental principles which he has stressed in war wounds should be carried over into civilian practice. We have believed that primary closure of wounds in civilian life is the method of choice rather than to close open wounds secondarily which could have been initially managed by primary closure.

Kenneth F. Lowry (closing): I want to thank Dr. Snyder and Dr. Siler for their comments.

In answer to Dr. Snyder's question regarding the use of vaseline gauze, I will admit that I have continued to use it. However, I insist that it be very lightly impregnated with vaseline.

With reference to the use of sulfanilamide locally I realize that it fell into some disrepute and was officially discontinued by the Army Medical Corps. This is perhaps not the time or place to get into an argument over that; however, I admit that I am still rather partial to the use of sulfanilamide in small quantities in the freshly débrided wound. As a supplement to systemic therapy I believe that it puts the chemotherapeutic agent where it is most needed. When properly applied it has not, in our experience, interfered with tissue repair.

In answer to Dr. Siler's comment, as you know, several years ago Reid and Carter advocated the excision *en bloc* treatment of traumatic wounds. I believe that this procedure is very good and very satisfactory in superficial wounds. However, in wounds associated with considerable trauma and wounds that are quite deep we do not use it. You will note that there is a considerable excision of skin necessary and, as I previously pointed out, the skin is particularly resistant to infection. I believe you can visualize that if this procedure is followed, the danger of injuring major nerves and blood vessels which may be lying at the depth of the wound is rather obvious. If, however, one can use this type of excision *en bloc* procedure in a fairly superficial traumatic wound primary suture is, of course, justified. The method of débridement which we described is, of course, a procedure of piece-meal excision of traumatized and devitalized tissue. It is accomplished within a potentially if not actually infected tract and, therefore, has no pretention of being an aseptic operation. It insists on the exposure of the full extent of the wound tract thus minimizing possible injury to vital nerves or blood vessels.

We believe that in many wounds encountered in civilian life primary suture can be safely accomplished if you keep the patient under constant observation afterward, a situation which rarely exists in war. However, we still insist that these wounds associated with marked tissue destruction, contamination or a prolonged time lag are more safely handled by delayed suture.

TREATMENT OF HUMAN BITES OF THE HAND*

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REPORTS on the treatment of human bites of the hand have shown variations in the results. This paper analyzes the treatment of sixty-eight patients, some of whom were handled during the sulfonamide period and some during the penicillin era. An attempt is made to compare the results. This report does not purport to be a comprehensive review of the pathology of the subject as that was adequately covered in the classical paper of Mason and Koch.[1]

Certain features of the pathology and bacteriology cannot be too often re-emphasized as constant recognition of these facts leads to an appreciation of the magnitude of the problem and thence to rational therapy. The two authors pointed out that bacteria introduced through a knuckle of a clenched fist are carried well back up the hand as the tendon extends. The close interrelation of the hand spaces allows us to visualize the chain of events that frequently follow. Boyce[2] in an analysis of seventy-two cases pointed to the sites of spread in the order of frequency, namely, subcutaneous space, subfascial space, subaponeurotic space, metacarpophalangeal joints, fascial spaces of the palm and flexor tendon sheaths.

The bacteria commonly found in these lesions are Staphylococcus aureus and albus, the Streptococcus (viridans and micro-aerophilic), Bacillus proteus, B. subtilis, the fusiform bacillus and Spirochete of Vincent. Meleney[3] in discussing Boland's paper[4] placed great stress on the importance of the anaerobic streptococcus in these lesions. Just what has been the magnitude of this problem? The high incidence of radical surgery necessary in the collected cases presented by Welch[5] in 1936 shows the seriousness of the spread of infection. In presenting these cases Welch classified them as early, delayed and late. The early cases were patients seen within twelve hours of injury. The delayed were patients seen from twelve hours to a week. Late cases were those patients seen over a week from injury. (Table 1.) In this group the bacterial content did not appear to bear any direct relationship to the severity. Each of the organisms mentioned above was fairly well distributed throughout the series.

Cohn[6] pointed out that in twenty-eight early collected cases one arm and two finger amputations were done. In fifty-six delayed cases one hand and fifteen finger amputations were done. In twenty-three late cases nine fingers were amputated.

TABLE 1*

Total Cases	Early	Delayed	Late
Cases healed	5	9	7
Amputated finger	1	7	4
Amputated finger and metacarpal	..	2	
Amputated hand	..	1	
Amputated arm	1	1	
Died, sepsis	..	2	
Flail finger	1	1	
Stiff finger	1	1	
Left with osteomyelitis	1	..	1
Good function, recurrent sepsis	..	..	1

* From WELCH, C. E., Human Bite Infections of the Hand. *New England J. Med.*, 215: 901, 1936.

On the brighter side of the picture Bates[7] reported 100 cases in which the patients were treated by electrocautery without complications. As Welch pointed out these results are hard to evaluate as no details are presented.

Miller and Winfield[8] in an excellent presentation gave their results of treatment in sixty-one cases (early). (Table II.) The authors pointed out that these patients were all started on treatment before four hours. In these cases the average wound-healing time was 8.5 days. The last twenty-seven of these cases were particularly studied; in these the average healing time was 9.9 days. The authors then presented fifty-four late cases showing multiple infections of joints, fascial spaces and tendon sheaths. The average patient hospital time was 9.4 days; the total healing time was thirty-four days. In

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the latter group of cases considerable surgery was required. In the former it was negligible.

As one studies this question of human bites the aforementioned record in handling these cases is hard to beat. It is a testimony to the value of close attention to surgical principles.

TABLE II*

Location of Injury	Cases (No.)	Remained Clean	Mild Inflammation	Gross Infection
Compound fracture, finger	6	5	1	0
Finger	34	32	2	0
Knuckle	18	15	2	1
Palm	1	1	0	0
Dorsum	2	2	0	0
Total	61	55	5	1

* MILLER, H. and WINFIELD, J. M. Human bites of hand. *Surg., Gynec. & Obst.*, 74: 153, 1942.

The treatment in these cases was very similar to that to be described.

For purposes of discussion our own seventy cases were broken down according to the typing of Welch[2] as previously mentioned. A second classification was made, namely, those before sulfonamides, those treated with sulfonamides and those handled by penicillin. Two other factors enter in here. Some of the patients who received penicillin received sulfonamides in addition. Then, too, an awakened interest in these cases led to closer attention to the surgical principles mentioned hereafter.

Our case material was derived from two sources, namely, from the Police and Fireman's Ward and from the general surgical ward. Twenty-eight cases comprised the former group and the remainder comprised the latter group.

Measuring the success of treatment in this latter group has been difficult. This particular point should be stressed. The importance herein lies in the fact that many reports in the literature give the patient's number of hospital days on a certain type of therapy but do not report what happens to the patient after he leaves his inpatient status and goes out to clinic for follow-up care. It is a well known fact that many patients of the type handled in a city hospital clinic are satisfied simply when their pain is relieved. They are patients who do not seek medical care until the pain is unbearable. Usually they are kept in the hospital until the progression of the infection is controlled; then they are referred to the clinic for further dressing. Many of the wounds are still draining or granulating but are painless. A large percentage of these patients do not come back to the clinic. Attempts to follow this group find that they have either changed their address or are not interested. Not the least factor, however, is the fact that the shifting clinic personnel loses contact with the case early and fails to indoctrinate the patient in the habit of coming back for checkups. A plea might well be made here for the city hospitals which see most of these cases to establish a good follow-up on a large group of these cases. Such figures would help to establish a relatively standardized method for handling these cases.

TREATMENT

During the sulfa period intermittent hot soaks and elevation were the rule. Under the present regimen the affected hand is washed with soap and water. The wound is irrigated with large quantities of saline and left wide open. Any ragged edges are débrided. The hand and forearm are securely wrapped on a volar splint. Sterile gauze pads are placed over the region of the laceration and are moistened with saline. The splinted forearm is now placed on a half-ring splint and hung up to an intravenous standard at 45 degrees. (Fig. 1.) Additional comfort is added if a sandbag is placed beneath the upper arm. A hot water bottle one-quarter full is hung down off the intravenous standard onto the dorsum of the hand; then the whole splint is wrapped with a plastic wrapper to contain the moisture and the heat. (Fig. 2.) The patient is thus maintained on strict bedrest for forty-eight hours at which time the process is re-evaluated as to necessity for further immobilization. Adequate sedation must be given to offset the patient's impatience with bedrest.

Penicillin has been given preferably in large doses, i.e., 100,000 units every three hours. This large dosage was chosen after the question of penicillin-fastness had arisen in a few of the earlier cases tried with smaller doses to make the over-all actual dosage 63,000 units per three hours. Future figures are desired to see whether smaller doses will be as good. Not enough cases have been tried with the one shot per twenty-four hours technic to warrant any conclusions whatever.

The series of pre-sulfa cases here is too small to be of significance. One interesting point that

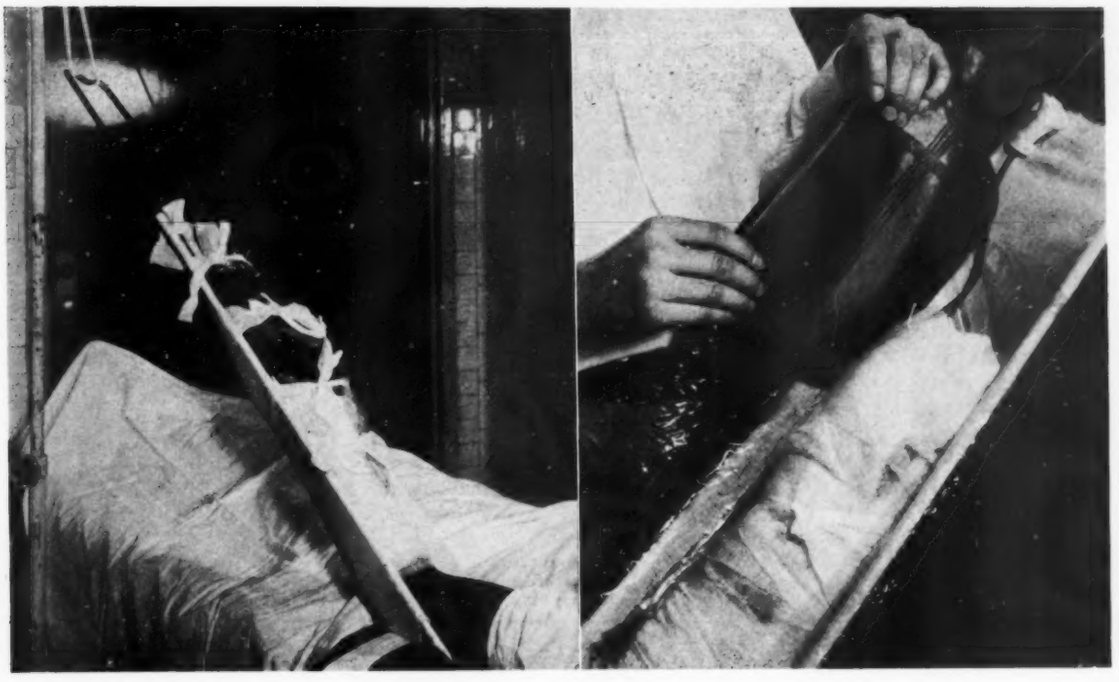

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FIG. 1. Sustained and comfortable elevation is assured by the use of the splint. Further comfort is promoted by the use of a sandbag under the upper arm.
FIG. 2. The forearm and hand are shown snugly approximated to the protected basswood splint by gauze. The hand and fingers are covered by fluffed gauze into which a sterile catheter is threaded. In actual use the hot water bottle is wrapped with towel then encased by the plastic wrapper shown.

it does bring out is that some of the late cases just happen to be associated with bacteria of low virulence and are not necessarily crippling as are some of the more sweeping infections. These patients were abruptly sent to the outpatient department.

Although Table III shows a considerable improvement in the number of hospital days, this column does not tell the entire story. The vast majority of the patients who received penicillin went out completely healed. A few patients sent out while wounds were granulating raised the average of the clinic days. Reference to the average number of clinic days under the sulfa period makes the improvement under penicillin more dramatic.

Tables IV and V show without comment the distinct improvement along all lines during penicillin regimen.

The one finger amputation under the delayed penicillin group was performed on an alcoholic who was discharged as improved for further dressings in the clinic only to show up in a few weeks with a necrotic finger requiring amputation. Eight of these patients were cauterized before coming to the hospital.

The role of cauterization is questionable. It is true, as previously mentioned, that Bates[7] reported in 1931 100 cases in which patients were treated by electrocautery. In this report he stated that their hospital did not have to admit any patient for human bites of the hand since 1925. In Table VI, however, are several patients severely enough infected after cauterization to require hospitalization. They did not develop any severe spreading complications. Measuring these cases against the rapid healing with bland soaks, immobilization and penicillin, we do not see the indication for cauterization.

Seventeen of these cases were sutured at other hospitals as well as here. This is mentioned only to be condemned. The greatly increased frequency of severe complications with suturing is well shown in Table VII. The relatively high number of wounds sutured indicates a lack of appreciation of the type of wound. It is well known that the victim in these cases is liable to lie about the origin of the wound and lead the physician away from realizing that it is a human bite. It will be noted that very few wounds have been sutured recently. Most of these occurred during the sulfa era. It is realized that this factor may have been a large contributor to the poor

TABLE III
COMPARISON OF RESULTS OBTAINED WITH SULFA AND PENICILLIN

	Pre-sulfa			Sulfa Period			Penicillin Era		
	Early	Delayed	Late	Early	Delayed	Late	Early	Delayed	Late
No. cases	3	2	3	10	16	3	9	20	4
Average time before started treatment	?	?	?	7.7 hr.	2.3 days	17 days	6.2 hr.	1.7 days	12 days
Average number hospital days	1	39	4.6	6.15	11	30	3.8	6.5	18
Average number clinic days in followed-up cases	..	..	...	29	29	.....	7	10.6	

TABLE IV
COMPARISON OF COMPLICATIONS IN SULFA AND PENICILLIN ERA

	Pre-sulfa			Sulfa Period			Penicillin Era		
	Early	Delayed	Late	Early	Delayed	Late	Early	Delayed	Late
No. cases	3	2	3	10	16	3	9	20	4
No. complications									
Osteomyelitis	..	..	..	2	1	3	0	1*	2
Thenar space infection	..	..	..	3	..	1	0	1	
Tendon slough	..	..	..	1	1	1	0		
Purulent arthritis	..	1							

* Penicillin not begun until thirteenth day; sulfa up to that time.

TABLE V
COMPARATIVE NEED FOR SURGERY IN SULFA AND PENICILLIN ERA

	Pre-sulfa			Sulfa Period			Penicillin Era		
	Early	Delayed	Late	Early	Delayed	Late	Early	Delayed	Late
No. cases	3	2	3	10	16	3	9	20	4
No. operations									
Incision and drainage	..	2	1	2	5	1	0	2	1
Finger amputation	..	..	..	0	0	0	0	1*	0
Metacarpal amputation	..	..	..	2	1	1	0	0	1

* Penicillin not begun until thirteenth day.

average in the tables for the sulfa period and that maybe the difference is not as attributable to penicillin as we think. More reports on this subject are necessary.

CONCLUSIONS

1. The results of treatment of seventy cases of human bites of the hand are analyzed.

TABLE VI
PATIENTS TREATED BY CAUTERIZATION BEFORE COMING TO PHILADELPHIA GENERAL HOSPITAL

Classification	Type Cautery	Hospital Days	Complications	Outcome
Early sulfa	?	3	Other than local sepsis —0	Good
Early sulfa	Electro	6		
Delayed sulfa	$AgNo_3$	7		Good
Delayed sulfa	Phenol	4 Av. 4		Good
Delayed sulfa	Electro	2		Good
Delayed sulfa	Phenol	3		
Early penicillin	Phenol	1		
Delayed penicillin	?	3		

TABLE VII
NUMBER OF PATIENTS SUTURED

Classification	Hospital Days	Clinic Days	Complications	Outcome
Pre-sulfa early	1	13	(Other than local sepsis)	
Pre-sulfa early	1	12	None	
Pre-sulfa delayed	2	30		Restricting scar
Sulfa early	30	6 wk.	Osteomyelitis of phalanx and metacarpal	Amputation
Sulfa early	2	30		Restricting scar
Sulfa delayed	8	6 wk.	Purulent Arthritis	Flexion disability
Sulfa delayed	2	?	?	?
Sulfa delayed	4	6 days		Restricting scar
Sulfa delayed	30	?	Osteomyelitis of phalanx	Painful but good function
Sulfa delayed	1	?	?	?
Sulfa delayed	4	?	Tendon slough	?
Sulfa delayed	4	?	None	
Sulfa delayed	10	?	?	
Sulfa delayed	8	?	?	?
Penicillin delayed	3	?	?	?
Penicillin delayed	5	?	?	?

2. We agree with Miller and Winfield that the most important single factor in handling human bites of the hand is to resort to the most scrupulous observation of surgical principles in the case of hand infections as outlined by Kanavel[9] and others.

3. Penicillin in adequate dosage combined with the aforementioned renders *early* cases of human bites of the hand almost innoccuous.

4. There is still not the general appreciation of the seriousness of these human bites and of the necessity for hospitalization. This is true of hand infections in general. More emphatic teaching on this point is necessary.

5. Suturing of these wounds is condemned.

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DISCUSSION

VINTON E. SILER (Cincinnati, O.): Dr. Grimes has given us a very excellent presentation of human bite infections and I agree for the most part with everything he has said.

The biggest problem in the care of this condition is to teach the house staff, particularly the admitting service of the hospital, the necessity for seeing these patients as soon after admission to the receiving unit as possible to direct therapy from that point.

One of the greatest problems is to send these patients home without any therapy whatever. The majority of our human bite infections are in patients who are under arrest and have been taken back to jail only to return to the hospital some forty-eight to seventy-two hours later with a very serious infection of the hand.

I might say one word about chemotherapy. Unquestionably it should be given, particularly penicillin, at the rate Dr. Grimes has mentioned. Along with it we would certainly advocate using streptomycin. There are reasons to believe that chloromycetin will help control these infections even better.

I think there must be some distinction made with regard to the depth of the initial wound. Those that penetrate the capsule of the metacarpophalangeal joint are much more serious in our own hands than those that just penetrate the skin.

JOSEPH POSCH (Detroit, Mich.): I would like

to say that I enjoyed Dr. Grimes' presentation very much. I would like to outline briefly the treatment of our hand injuries at the Detroit Receiving Hospital.

As has been mentioned, the patients are often seen very early and at that time a thorough washing is done for at least fifteen to twenty minutes. At the conclusion of that period the wound is débrided according to the depth of the injury. The superficial areas are débrided and left open. It was mentioned in Dr. Grimes' paper that they should not be sutured, and we would like to re-emphasize that point.

Recently we had a patient who was admitted with a severe infection of the back of his hand. He had a small laceration that had been sutured. He denied suffering a human bite of any type, but on going into his history we found that he had been in a scuffle. How he became injured he did not know. Clinically, it looked exactly like a human bite. This required thorough opening in the operating room under a tourniquet and brachial block anesthesia; at the present time he still has a residual arthritis.

Another case I would like to mention just briefly is a patient who had a seven-day old neglected human bite of the thumb. He was admitted with a superficial abscess plus a thenar space abscess. He developed periosteomyelitis and eventually had an ankylosis of his thumb, with a resulting three months' unemployment.

I think a comment on the use of electrocautery is interesting. We have used no cautery and do not think it is indicated. We have not been using zinc peroxide, either, as mentioned by some authors. We are inclined to use a simple method such as thorough débridement and thorough washing.

Just one more point: I think a metal splint is always necessary for these for adequate immobilization. Because of insufficient hospital beds our early patients have not always been hospitalized but have been followed-up very carefully in the clinic and have been given seventy-two-hour penicillin twice weekly.

HARRY MILLER (Allentown, Pa.): I would like to point out the importance of early treatment of human bites. It is our belief that a human bite twelve hours old is already a late human bite. Unfortunately they usually came to us late.

In 1939 at the Detroit Receiving Hospital Hand Clinic under the direction of Dr. Chas. G. Johnston, Dr. Spears, Dr. Winfield and I studied the prophylaxis of human bite infections. It was our belief that in order to prevent the later complications and sequelae of human bites it was essential that these patients be seen and treated immediately. Thereupon, it became the duty of the resident on service to report to the admitting room and see these patients personally and direct their therapy.

The original treatment was that of shaving the surrounding skin, washing the surrounding areas of the wound for about five minutes and then continuing the soap and water washing for a full ten minutes. That was followed by limited débridement. If there had been penetration into the joint or laceration of the tendon or compound fracturing of the metacarpal, hospital admission was urged. Débridement was done in the operating room under general anesthesia following which the hand was splinted in a functional position and the patient returned to the ward where magnesium sulfate, Dakin's solution, boric acid or saline soaks were continued. If the patient was not admitted, treatment as outlined was carried out and the patient was advised to return to the hand clinic where he was seen within twenty-four hours. If evidence of infection was found at this time, the patient was admitted to the hospital for definitive treatment.

We believe that if the patient is seen within four hours, fewer patients will develop these sequelae and fewer will require hospital admission.

HARVEY S. ALLEN (Chicago, Ill.): Before the war, from 1938 to 1941, we had seen 327 human bites. Now we have changed our opinion a little with regard to the bites in the so-called antibiotic area. In the first place I think we should clarify what we mean by human bite. When we deal with a human bite that is only in soft parts, skin, subcutaneous tissue—incidentally we have had them all over the body, for example, the breast, face, leg, buttock, the tips of the finger—we are dealing only with a mixed but virulent infection. We have no closed spaces.

However, we still have our poor results in a wound of the actual fist-fight type in which a person may knock out a tooth and think he is the winner yet end up with a small ulcer over the metacarpal joint where the joint has been penetrated. If the soft parts only are involved, we have found that by the use of proper antibiotics, immobilization and, above all, hospitalization, our time is greatly reduced. In most cases in which the joint is involved we are still having complications of suppurative arthritis, adjacent osteomyelitis, fusion of the joint and often a stiff, useless finger.

We started first with anticipating that the hand would be stiff and, in using Kanavel's dictum of position or function, we anticipate that fusion may occur. We do not have the excellent findings of Dr. Grimes' but I am sure our hospitalization has been greatly shortened.

To reiterate, however, we are still very much depressed over the results that we are getting in those cases in which the joint cavity has been invaded.

EDGAR L. GILCREEST (San Francisco, Calif.): Wounds caused by human bites have interested me since my early days in Texas. As all of you perhaps know, that is a very common type of wound with

the negro. In a Saturday night fracas if a negro has forgotten his razor, he resorts to his teeth.

I remember so well a negro who was brought before the Court. The judge, looking at this poor negro and observing how he had been mutilated, turned to the other Negro, the defendant, and said, "In all my long experience I have never seen a human being so mutilated. When you tore open this man's mouth, the devil must have told you to do so. No human being could have thought of such a thing. When you flattened out his nose and gouged out his eye, the infernal demons must have been whispering to you." And the judge went on and on; but instead of the defendant becoming mortified, he became more and more proud. When the judge had finished, he said, "Yes sah, jedge, you're just 'xactly right. When I tore open his mouth, I could hear the devil telling me to do it; and when I flattened out his nose and gouged out his eye, I could hear the infernal demons whispering to me; but when I bit off his left ear, jedge, that was just *my own idea!*"

JOHN C. A. GERSTER (New York, N.Y.): That was a perfectly marvellous paper. I think from it we surgeons could take a good bit of advice regarding accidental wounds of our own and of our assistants in the operating room. I have seen some terrible infections, almost crippling ones, in surgeons old and young who disregarding an accidental puncture by a knife, sharp retractor or needle when operating in an infected area and failing to put the injured finger immediately at rest, went on operating with this infected puncture of their own finger which went on being massaged by the manipulations incidental to completion of the operation.

At one clinic abroad the minute an operator was accidentally injured he was sent away from the table and had his injured hand immobilized for from twenty-four to forty-eight hours. The chief of this clinic had lost one of his favorite assistants from sepsis of this sort. And so it is something we might bear in mind—the great principle of immediate rest as a safeguard against spreading of infection. Nowadays we have the sulfonamides and all the antibiotics but it is still well to stress the principle of rest as beautifully as Dr. Grimes has stressed it.

LEWIS C. MANGES (closing): For many years this type of wound has been causing us a great deal of trouble among the policemen of Philadelphia. Dr. Hubley Owen, formerly the Police Surgeon of Philadelphia and a member of this organization, stimulated my interest in this injury. Although we believe that we are now able to treat this type of wound satisfactorily, as time goes on we may find that our problem is not completely solved. Dr. Allen states that he is still having trouble in spite of the more modern treatment. For a while we thought that excising these wounds and doing a primary suture was the best method of treatment. For approximately a year we had very little trouble and then we found a great deal of it. After Meleney's paper we attempted to use zinc peroxide. This, as proved by many people, was not the answer to the problem.

Dr. Miller, we have trouble getting these cases in four hours. In spite of our educational program among policemen, we have been unable to impress them with the seriousness of this injury. It is usually well past the four-hour period before they first present themselves in our Clinic. When we first seriously faced this problem, we tried three methods of combatting it. First, we tried to educate the policemen that this was a hazardous injury which should be treated immediately. This was of little avail. We then tried to educate the interns in the hospitals of Philadelphia that this was a special injury which should be given special treatment. This worked for a while until the interns were changed and we soon had the same trouble. The interns insist upon either suturing the wound or cauterizing it with silver nitrate, nitric acid or actual cautery. Dr. Bates' paper did not help us very much in Philadelphia. I think he was sincere in his paper but we could not substantiate his results. We still receive patients that have been cauterized before they are sent to our Police Clinic. Since we have been using penicillin, we have had very good results, particularly when treated as Dr. Grimes has described.

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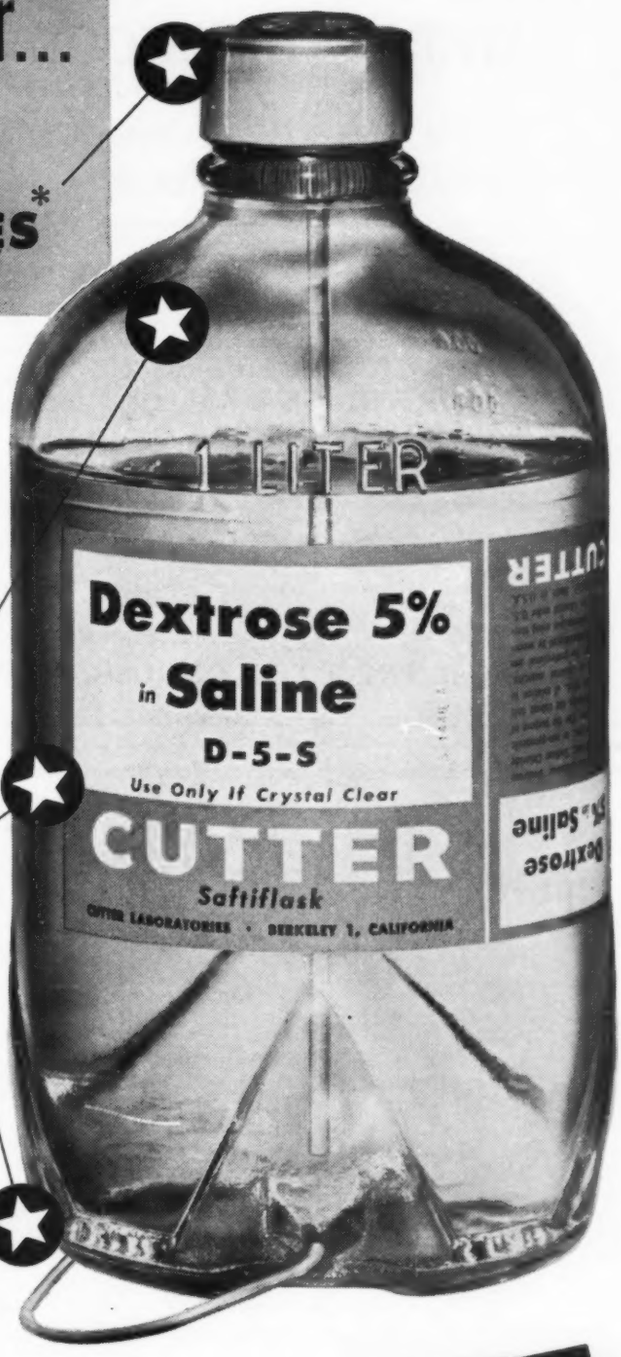

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Outside the Ivory Tower

(*continued from page 20*)

It will be acknowledged that anyone engaged in this sphere of medical endeavor would do well to possess these invaluable reference books. Maya Riviere has done a splendid editorial job. The price is $10.00.

TO those interested in the subject we recommend "The Science and Art of Joint Manipulation" by James Mennell, M.A., M.D., B.C., etc. This is a second edition. Volume 1 deals with the extremities. It is well illustrated (299), well written, covers 215 pages and has a good index. The Blakiston Company publishes the book and it costs $7.50.

THE Ciba award for meritorious work in endocrinology will again be offered in 1949. This Ciba award will be given in recognition of the accomplishment of an investigator, not over thirty-five years of age, in the field of clinical or preclinical endocrinology. This award is $1,200.00. If within two years of the date of the award the recipient chooses to use it to aid work in a laboratory other than the one in which he is normally located, the award will be increased to $1,800.00. The winner of the Ciba award for 1949 will be announced at the annual meeting of the Association for the Study of Internal Secretions. A special committee of five members of the Association chooses the recipient of this award subject to ratification by the Council of the Association. Each member of the Association has the privilege of making one nomination for the award.

TAKING advantage of the fact that polyethylene is non-irritating and does not induce clotting Clay-Adams Company, Inc. of 141 East 25 Street, New York 10, New York is now producing polyethylene catheters for replacement transfusion. Use of these catheters results in considerable simplification of the technics of replacement transfusion in newborn infants with erythroblastosis fetalis and of constant intravenous therapy in older children and adults. Adams polyethylene catheters can be sterilized by use of a bland antiseptic such as Zephiran Alba, 1:1,000 solution and may be left in the sterilizing solution until needed. These catheters are supplied carded in 10 foot lengths and in boxes of ten cards.

THE committee appointed by the National Academy of Sciences for the allocation of Cortisone will be given full and complete cooperation by Merck and Company, Inc., George W. Merck, president, announced. He said that this committee provides an orderly means for advancing knowledge of this new hormone and best serves the public interest. The company supplied Cortisone to the Mayo Clinic, Rochester, Minnesota, in September, 1948, for the first clinical studies in rheumatoid arthritis made by Drs. P. S. Hench, E. C. Kendall, C. H. Slocumb and H. F. Polley. Mr. Merck announced that the company is taking all possible steps, based on present scientific knowledge, to increase production of this new product. It is expected that the amount available from the company's laboratory production program will be increased the latter part of this year but supplies will be sufficient only to take care of clinical and other research studies. The material made available by Merck to the committee of the National Academy of Sciences will be allocated solely and independently by the committee to institutions and clinics for their studies.

THREE years ago the first shipment of radioactive elements, radioactive isotopes, was made from the atomic furnace at Oak Ridge National Laboratory for use as tracer atoms by researchers in the United States. Today, on the third anniversary of the initiation of the distribution program, the Isotopes Division of the Atomic Energy Commission here announced that a total of 7,613 shipments have gone to various institutions and individuals for use as invaluable tools of science, agriculture, medicine and industry. In addition, 750 shipments of separated, non-radioactive stable isotopes were also made. To date over 1,850 scientific and technical publications describing isotope studies have been made, with approximately 200 papers being published each month. Of the total number of shipments 7,025 have gone to research laboratories and hospitals in the United States. Since September, 1947, when the foreign distribution program was announced, 588 shipments have gone to researchers in twenty-one countries.

(*continued on page 39*)

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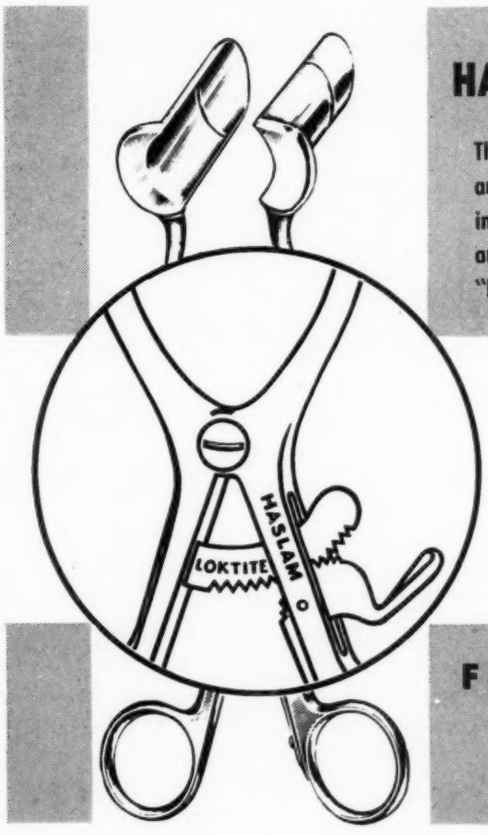

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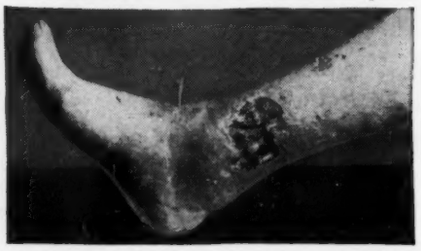

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* Pain Syndromes—Judovich, B. & Bates, W.
* Bulletin of Mayo Clinic, Sept. 15, 1948, pp. 443 and 447.
* Bibliography on request.

(*continued from page 36*)

THE American Urological Association offers an annual award of $1,000 (first prize of $500, second prize $300 and third prize $200) for essays on the result of some clinical or laboratory research in urology. Competition shall be limited to urologists who have been in such specific practice for not more than five years and to residents in urology in recognized hospitals. The first prize essay will appear on the program of the forthcoming meeting of the American Urological Association, to be held at the Hotel Statler, Washington, D. C., May 29 to June 1, 1950. For full particulars write the Secretary, Dr. Charles H. de T. Shivers, Boardwalk National Arcade Building, Atlantic City, New Jersey. Essays must be in his hands before February 20, 1950.

A NEW virus which at times causes a disease closely resembling poliomyelitis in its non-paralyzing form has been reported by scientists at Yale University. This new virus has been isolated as a result of studies of last summer's poliomyelitis outbreaks (1948) in southern New England, North Carolina and Texas. This finding confirms a discovery originally made at the New York State Department of Health Laboratories last year. The origin of outbreaks of the new disease is unknown and its means of transmission is obscure, but the symptoms of the disease are at times identical with those of mild poliomyelitis. It has been found to occur simultaneously with poliomyelitis in the summer season. Thus in several cities where poliomyelitis was prevalent last summer people who were diagnosed as having poliomyelitis were found to be infected with this new virus. It seems, on the basis of present cases studied, to inflict no permanent injury and all those patients who have been studied by the Yale group have recovered with no harmful after-effects. The average length of illness is approximately ten days. The new virus has not yet been officially named.

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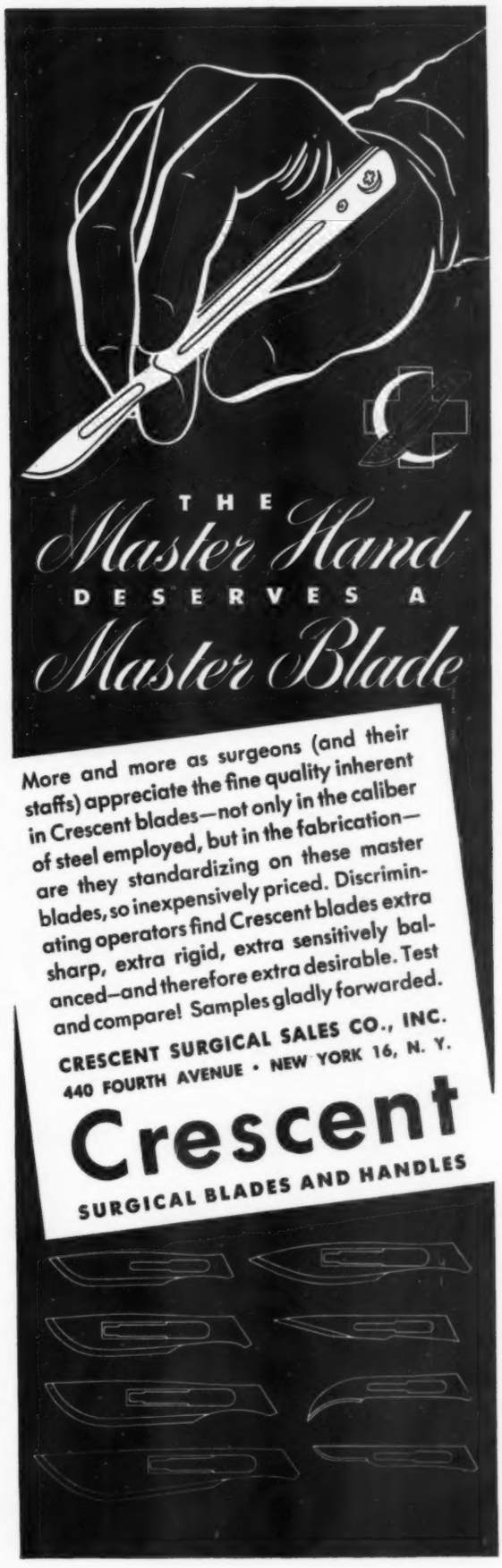
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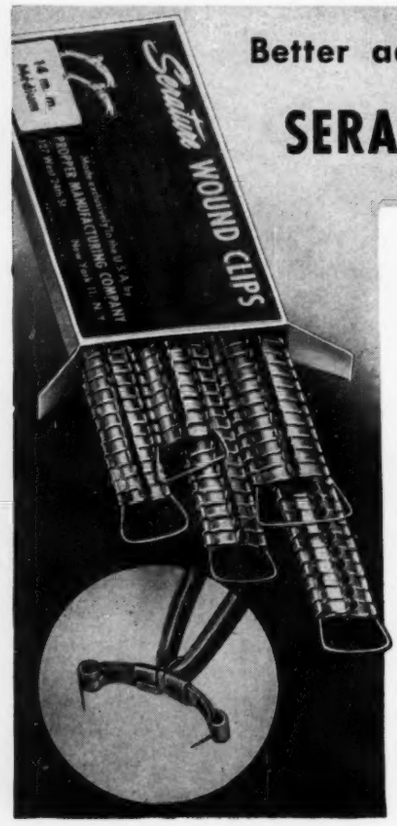

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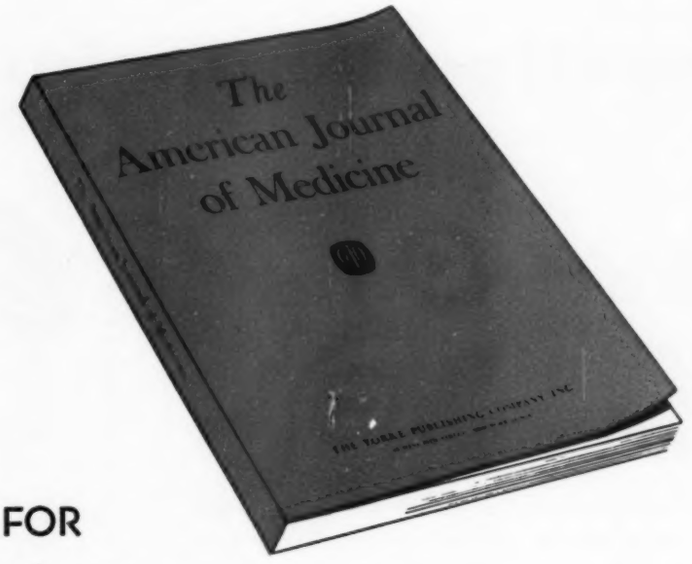

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